A Review on *Tapered Slot Antenna Systems Operating at Mid-band and High-band Frequencies*

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Abstract - *In this paper, an overview of existing designs of tapered slot antennas at Sub-6 GHz and mm-wave frequencies are presented. A Vivaldi antenna is a type of tapered slot antenna known for its wide bandwidth and high gain characteristics. It is a good choice for more reliable wireless communication. This survey is about the new advancements in Vivaldi antenna design which enhanced the performance at Sub-GHz and mm-wave frequencies. 5G which is a combination of Sub-6GHz and mm-wave frequency bands can provide coverage along with high speed data services in required locations by maintaining less delay. As per 5G communication network demands Vivaldi antenna is well suitable.*

Key Words: Literature survey, tapered slot antenna, Vivaldi antenna, 5G, Sub-6 GHz, mm-wave frequencies.

1.INTRODUCTION

Due to the broadband capabilities, high gain and directional properties Vivaldi antennas [1] which are novel member of the class aperiodic continuously scaled antenna structures are widely used in various applications and domains such as wireless communication systems, radar systems, satellite communications, medical imaging and high-power jamming systems etc. In the 5th generation the swift evolution of wireless communication technologies resulted in excellent data speeds, minimized latency and expanded connectivity. Among the diverse antenna systems available in market tapered slot antennas which are class of end fire antennas consisting an exponentially tapered slot supports broad range of frequencies. As per 5G network performance demands tapered slot antennas are well suitable especially Vivaldi antenna systems which provides exceptional performance in both Sub-6GHz and mm-Wave frequency bands.

1.1 Vivaldi Antenna

The operation principle of Vivaldi antenna which is a specific type of tapered slot antenna is when a wave propagates along the beginning of slot line due to exponential tapered slot pattern the wave results in highly directive beam as it gradually radiates from the mouth opening [2]. According to theoretical background of the tapered design [3], an exponential tapered slot with feed slot results as a Vivaldi antenna. The end points of the taper $p_1(x_1, y_1)$ and $P_2(x_2, y_2)$ the opening rate R can be defined by an exponential equation (1) as given below

$$x = c_1 e^{Ry} + c_2 \qquad (1)$$

Where,

$$c_1 = \frac{x_2 - x_1}{e^{Ry_2} - e^{Ry_1}}$$

$$c_2 = \frac{x_1 e^{Ry_2} - x_2 e^{Ry_1}}{e^{Ry_2} - e^{Ry_1}}$$

This kind of Vivaldi antenna design enables to achieve a broad range by covering several octaves of frequency making it good choice for 5G communication systems. Vivaldi antennas having unique tapered slot patterns, inclined groove, matching circle and required corrugations will allow the antennas to have a good impedance match that enhances the performance of antenna system in terms of gain, directivity, broadband and radiation patterns. The advantages of Vivaldi antenna system include high gain, low cross polarization, directional radiation, broadband and compact size.

1.2 Substrate based Vivaldi and All metallic Vivaldi antennas

Vivaldi antennas can be designed using various dielectric materials such as FR4, Rogers-5880, etc.as their base support. This kind of antennas are expensive and also reduces the gain efficiency, bandwidth performances of antenna due to its dielectric properties. Even though substrate-based Vivaldi antennas provide design flexibility and ease to fabricate use of dielectric substrate in construction have impact on antenna performance. There is always a tradeoff between gain and bandwidth due to the impact of dielectric properties. One solution to mitigate this is use of all metal Vivaldi antennas made up of copper, aluminum, etc. These all metal Vivaldi antennas can provide high conductivity and gain at lower frequencies and eliminates dielectric loss, more robust compared and are very suitable for telemetry, satellite and high-power jamming applications [4], [5], [6].

1.3 Fabrication Methods

The antenna designs with improved performance characteristics can be produced by various advanced fabrication methods such as 3D printing/Additive manufacturing [4]. The complex design structures having multiple internal slots or corrugations can be easily manufactured by selective later melting [6]. Additive manufacturing can rapidly prototype the antenna with complex geometries. The substrate based and all metallic Vivaldi antennas are fabricated using laser cutting, CNC milling, etc. which offer good precision.

1.4 5G and frequency usage

The tradeoff between the coverage and data speeds can be mitigated by the combination of mid band Sub-6GHz and high band mm-Wave frequencies [10]. The Sub-6GHz are mainly used in urban and suburban areas are typically between 1 and 6GHz, such as 2.5,3.5 and 4. 7GHz.They provide better coverage as they can easily penetrate into obstacles. The property of having longer wave length compared to mm-Wave provide better coverage and acceptable latency as they easily penetrate through obstacles like buildings, walls, etc. mm-Wave frequencies mainly used in densely populated areas for augmented reality and high definition video streaming applications range between 24 and 100 GHz such as 26,28,39 and 60 GHz can offer high data rates and very less latency of about 1ms. The coverage area is less than Sub-6GHz as they are shorter wavelength which easily gets absorbed by rain, obstacles etc.

1.5 Vivaldi antennas in 5G networks

As mentioned earlier Vivaldi antenna is an ideal candidate for 5G networks as they provide broadband performance, directional radiation pattern and high gain in a specific direction which can be used in radar systems for transmission and reception of signals [13]. They also exhibit low cross polarization levels for minimizing interference to maintain signal integrity. The compactness of Vivaldi antenna is one of the advantages for integrating it into space constrained devices and satellite applications [9]. In conclusion, the Vivaldi antenna with good fabrication technology and integration can provide the performance demands of 5G networks effectively.

2. LITERATURE SURVEY

In paper [4], authors designed and fabricated a high gain and bandwidth all metallic Vivaldi antenna for airborne UWB and power telemetry applications. The design evolution of this Vivaldi antenna first consists of tapered profile then horizontal cut and a rectangular cavity. The final design geometry is horizontal slot cut connecting tapered profile and rectangular cavity. Authors in this paper fabricated the designed antenna using two methods i.e. by 3D additive manufacturing and CNC milling. The antenna is designed for 6-11GHz frequency range. The additively manufactured antenna provides a gain of 4.95dBi, bandwidth of 4.70GHz and 52.86% fractional bandwidth. Whereas CNC milling based antenna is able to provide better performance in terms of 5.70dBi gain, 4.95GHz bandwidth and fractional bandwidth of 56.73%. The antenna offers efficiency of 94% at center frequency 8.5GHz. They fabricated antenna top and ground parts in separate to easily insert a long pin coaxial SMA connector using J-B weld marine weld white epoxy adhesive paste. According to centre frequency 8.5GHz the slot width is taken as $\lambda/2$ and metal thickness as $\lambda/4$.

Due to the white epoxy adhesive pastes the measured results are slightly degraded compared to simulation results. NS12000 antenna measurement system of measuring capacity 0-40GHz and NSI-RF-WR 340 wave guide reference antenna is placed 1.75m apart to measure the fabricated antenna. Around 450 USD is spent to fabricate the additive manufactured and CNC based antenna which is better than 1000 USD PCB fabrication. The compact Vivaldi antenna of dimensions 20mmx20mmx29mm in with wide operational bandwidth, high gain and directed beam is designed and fabricated. It is verified through results that antenna fabricated using CNC milling provide 1.2x better results than additively manufactured antenna.

In paper [5], a novel 2-50GHz UWB all metallic Vivaldi antenna having wide impedance bandwidth of 25:1 with loss better than 10dB for applications like radar, biomedical detection, UWB communication systems, plasma microwave diagnostics is presented. The antenna system consists of 3 components namely Vivaldi metal plate, 2,4mm-k connector and a supporting ground plate. The geometrical structure of Vivaldi metal plate includes and inclined groove connecting tapered slot pattern and matching circle. At the beginning of inclined groove and close to matching circle a 2.4mm-k connector with reflecting ground is fed to antenna. The required corrugations at both legs of antenna are included to enhance performance in terms of gain, bandwidth, radiation pattern and to reduce weight of antenna. Electromagnetic waves are easily transmitted and radiated because the Vivaldi tapered line and the feed line are smoothly connected without sharp edges. The high precision antenna is made out of aluminum sheet with thickness of 2.5mm machined using wire cutting technology and also provides structural reliability, low cost compared to PCB technology which cannot withstand high temperature and harsh environments. In order to improve directivity of the antenna, optimize the side lobe level and to provide support the reflective ground plate which is included have slight impact on antenna reflection coefficient. They mentioned that as the frequency increases the electric field strength increases on the reflective ground and matching circle of antenna which makes important effect on radiation for high frequency bands also most of the energy is getting radiated not reaching the end of Vivaldi system as the frequency increases. The Vivaldi antenna of size 530mmx400mm with gain of 4-12dBi provides wide bandwidth as the tapered line and the feeding structure are continuously connected which makes the EM waves to propagate smoothly. This can be mainly used for high vibration applications and is measured using Agilent vector network analyzer E8364B.

In paper [6], authors talk about all metallic antennas in high power jamming systems that are deployed in vehicles, aircrafts, ships or portable units for transmitting broadband interference RF waves to disrupt the enemy radar communication and navigation systems. They designed and fabricated an all metal Vivaldi antenna of dimensions 125mmX30mmX4.2mm turned into 8X8 array which is dual polarized with operating frequency of mid-band frequencies 3-6GHz. In order to reduce the fabrication complexity and time the selective laser melting (SLM) 3D printing method with high power laser is used to generate the thick metal structure. The array antenna is fabricated by melting and fusing aluminum metallic powder as it is delicate, cost effective and long-lasting at high temperatures. SLM is commonly used to fabricate complex internal antenna array system geometries and ground plate as it provides good precision. Authors propose a wide-angle impedance matching (WAIM) layer which is mounted on the top of 8x8 array antenna that is fabricated using a TLY-5 substrate with a thickness of 1.53 mm to improve the beam steering performance. Results show that WAIM layer improves measured active reflection coefficient (ARCs) of antenna system by an average of 4dB.The Vivaldi unit cells fed by SMA connectors are bolted to ground plate. The 8x8 array Vivaldi antenna system with $\pm$45-degree slant configuration having radiating flares are adjusted to produce high directivity and minimum pattern distortion and an inner cavity which has significant impact on the impedance matching characteristics enables broadband operation is a good candidate for high power jamming systems as the measured and simulated gains are 19 and 20.6dBi which are stable and are even observed at wide steering angles without formation of unwanted grating side lobes. It is mentioned that if this antenna is fabricated with dielectric substrates low durability characteristics are offered under high power operations. Results confirm that antenna geometry having rounded cornered rectangular inner cavity reduces the occurrence of arc flashes by decreasing the electric field distribution.

In paper [7], a novel dual polarized all metallic Vivaldi phased array for ultra-wide band, radar applications are designed and fabricated. Agilent E5071B vector network analyzer is used to test the fabricated antenna with active transmitter /receiver modules. The antenna of dimensions 30mmX10mmX4mm turned as 8X8 array consists of independent structural elements adaptable for forming arrays is fed by 50-Ohm SSMP connectors for operating frequency range of 6-18GHz providing 3:1 bandwidth and good scanning properties. The antenna geometrical structure consists of tapered slot, feed slot and rectangular matching cavity and it is fabricated from an 2A12 aluminum alloy using wire cutting technology. Authors developed an all metallic Vivaldi antenna array consisting of independent structural elements which can be easily integrated or withdrawn from the aperture. In contrast to existing metal Vivaldi antenna designs authors gave importance on enhancing the structural adaptability of the proposed antenna. The gain ranges from 15-24dBi with efficiencies more than 91% over the complete bandwidth. It is noted from the results that proposed antenna array shows impressive beam-scanning properties in elevation and azimuthal plane by maintaining no grating lobes across the scanning range. The resonant fields formed due to air gap structural discontinuity leading to degradation of antenna array performance are removed to establish optimal performance throughout the overall spectrum by introducing an absorbing material into metal Vivaldi leg. This absorbing material without disturbing the antenna performance suppressed the resonant fields developed and enhanced the antenna array functioning in the working frequency range. A rectangular groove of 3mmX6mm is created on side of Vivaldi leg. Ec cosorb BSR-1 of 2.5 mm thickness absorbing material having operating frequency of 6-35GHz is pasted on the side of Vivaldi leg which not only reduces resonance but also improved the impedance matching of antenna array.

In paper [8], a flush mountable ultra-wideband, lossless cavity-backed Vivaldi phased array antenna for advanced wireless communications in airborne systems is designed and fabricated. The antenna of size 112mmX18mm is a bidirectional antenna covering a wide bandwidth of 1-7GHz with maximum gain of 5dBi, and efficiency of 90%. The entire antenna system is made of all-metal aluminum which is fabricated using multilayer stacked all metal printed circuit board technique. The 3X4 array antenna system consists of 3 elements in elevation plane and 4 elements in azimuthal plane. The antenna geometry consists of inclined groove connecting tapered structure and rectangular coaxial line. The thickness of antenna is 6mm to easily mount the coaxial connector. The antenna array is embedded into lossless rectangular metallic enclosure where the bottom part of array is attached to cavity base. Authors examined the resonance between antenna and side walls of rectangular cavity in two principal planes using natural vibration mode analysis. The produced resonance within the band impacted the antenna performance. Authors concluded that resonance occurred at cavity base due to bouncing of currents generated at the transmission line which is created because of space between the array edge elements and cavity. High resonant modes created as currents due to stronger interaction with the cavity are less radiated prior reaching the aperture. To mitigate the resonance produced authors explored two methods. First approach is including resistors to antenna's resonator section which helps in eliminating the resonances by dissipating the reflected currents. Second approach is reducing the gap between antenna elements and cavity by shorting the antenna array elements to cavity. Authors developed a resonant free all metal Vivaldi antenna array system without using any absorbing materials by taking proper care when integrating the array inside the cavity over 5:1 bandwidth.

In paper [9], design of a super wide band planar Vivaldi antenna covering large operational band 3-27GHz is proposed. This antenna can be mainly used in applications like wireless communication, biomedical detection, Radar and Satellite communication systems. This compact Vivaldi antenna of dimensions 45mmX35mmX0.79mm produced maximum gain of 10dBi, with radiation efficiency above 95% and VSWR of 1.07 over the wide operating range. The proposed antenna for lower 5G and satellite applications has unique geometrical structure consisting of 10 rectangular corrugations ,2 circular slot of radius 5mm on the legs of Vivaldi to improve the gain, radiation directivity and operating frequency range. At the edge of tapered slot pattern a circular matching slot of radius 5mm is included to enhance the impedance matching. Authors found difficulty in miniaturization of antenna without disturbing the wide operational characteristics. It is mentioned that trade-off between the size of Vivaldi antenna and wide operating bandwidth is managed by using sweep parameter method to optimize the dimensions of the antenna, slots resulting in a compact antenna system with wide band operation. To improve the quality of service and cost of manufacturing authors developed this compact antenna system which provides excellent performance characteristics. The thickness of copper radiating patch is around 0.035mm and microstrip feed line is used to excite the corrugated tapered slot antenna. The simulated results are verified using three electromagnetic simulation software tools FEKO, HFSS and CST.

In paper [10], as the 4G and Wi-Fi bands have limited bandwidth and limited data rates that makes wireless communication unreliable authors develop a multiport common aperture 5G antenna system which can support Sub-6GHz and wide bandwidth mm-Wave frequencies. The antenna of entire size 75mmX25mmX0.254mm is designed according to mobile device width dimension on Rogers-5880 substrate. The common aperture antenna system consists of dipole, tapered slot and rectangular slot working for Sub-6GHz at 3.6GHz and mm-Wave at 28GHz. The authors first designed a 3.6GHz dipole antenna excited by a rectangular slot of length quarter-wavelength, then changed it as tapered slot modified feeding with low pass filter which can work as 28GHz tapered slot mm-Wave antenna. On the either sides of dipole arms two mm-wave tapered slot antennas are developed. Authors designed an additional feeding structure to excite the rectangular slot formed due to dipole antenna and ground plane. This rectangular slot can work at 1.9GHz and 5.2GHz lower frequencies. The antenna system design is fine tuned to get required performance of Sub-6GHz band at 3.4-4.4GHz, 1.87-1.94GHz and 4.6-5.6GHz, mm-wave band at 25-32GHz.The authors examined a real time situation by integrating the antenna system as practical mobile terminal with a large ground plane. Results proved that increasing the length of ground plane has no negative impact on antenna performance. The multi-port multi antenna developed for compact and integrated wireless devices is able to produce overall system gain of 8dBi with mm-Waves scanning area of 120 degree.

In paper [11], an all metal Vivaldi antenna operating for a wide frequency range of 3-18GHz is designed and fabricated. As the electronic warfare and communication systems mainly require 1-18GHz ultra-wideband antennas the proposed antenna is a good candidate for direction finding and phased array applications. The all metal Vivaldi antenna of size 140mmX24mm is machined using wire cut technology from aluminum material. All metallic 8X8 Vivaldi antenna array of geometrical structure having tapered slot, inclined groove and a rectangular cavity for impedance matching weighing lesser and easier to install in systems is designed and fabricated which can be thoroughly used in direction finding systems and other applications. The authors examined the antenna performance in terms of gain, bandwidth and radiation patterns through parametric analysis. It is found that antenna length is chosen to be 140mm as it has important effect on bandwidth, the rectangular cavity length and width has no effect on antenna performance. For mechanical support antenna having side and back walls is designed which slightly effects the antenna bandwidth performance compared to antenna designed without side and back walls. The linear array all metal Vivaldi antenna operating for a wide bandwidth of 4.6-18GHz, return loss of -7.5dB and gain varying from 3-8.7dBi at different frequencies is developed for direction finding and phased array applications.

In paper [12], authors developed a novel dual polarized all metal array antenna system of size 176mmX176mmX19mm through precision machining out of 6061 aluminum material. They fabricated a 10X9 all metal antenna array to examine the performance. Authors claim that the proposed antenna is good candidate for space-based radars as it is high temperature and vibration resistant and contains high power capacity. The proposed ultra-wide band phased array antenna with large element spacing has operating frequency of 2-10GHz with 90% radiation efficiency. The single element of size 15mmX15mmX19mm consists of a radiating dipole with two coupled blocks, a perturbational metal column block, and a reflective ground plane. To maintain physical stability, each element arm is connected to the ground plane. Authors designed a removable perturbational metal column block which is connected to ground plane. The designed elements can scan up ± 60 degrees in all planes. The weight and cost to manufacture antenna array increases if the number of transmitter/receiver modules increase within the same aperture due to small element spacing. Authors introduced a unique arrangement of dual polarized all metallic phased array antenna to overcome this element spacing limitation. The resonance occurred at high frequency is illustrated by an equivalent rectangular resonator model and is shifted from 10 to 11GHz by adding metal column block on the ground. Results show that adding perturbational metal column block enhanced the bandwidth at lower and high frequencies.

In paper [13], a unique featured phased array, tapered slot, all-metallic thick flared-notch radiator array operating at 700 MHz-9GHz ultrawide band is proposed. The antenna system is analyzed on the finite element method using an in-house Navy code (CEMNAV-INF) which produced comparable output to commercially available software. Considering conductivity and weight entire antenna system is fabricated of aluminum 6061 material using high precision wire-EDM cutting technology to ensure and repeat the simulated operating bandwidth when measured. Antenna geometry consists of a flared-notch and a rectangular slot which is bend 90 degrees perpendicular to the direction of radiation for feeding the coax straight into base of element. Authors fabricated two prototypes' out of their design – 32 element array of single polarization and 8X8 planar array elements of dual polarization. The antenna dimensioned 131mmX18mmX2.5mm provided a gain of 5dBi with 97% radiation efficiency, it scanned 45-degree area in all planes with 8:1 bandwidth and broadside scanning with 12:1 bandwidth. The SMA connector is slightly modified by extending center pin with a fuzz-button which is a minute cylindrical spring device that creates an electrical contact when it is directly screwed onto the antenna element without any soldering. The designed antenna is simpler to assemble and disassemble from the application systems and it is easily reproduceable due to its simple geometries with minimum cost. Measured results of presented 32-element linear array and 8X8 planar array provide high bandwidth and low VSWR similar to simulated results. Poor cross polarization performance is major limitation of this antenna array.

In paper [14], as Vivaldi array is capable of providing wide bandwidth and dual polarization conditions a novel dual polarized all metallic Vivaldi antenna array having wide operational bandwidth for airborne radar systems of snow applications is designed and fabricated by the authors. The manufactured Vivaldi antenna is able to precise map the snow-air and ice layers to determine the thickness. It also provides polarization-based measurements of snow on sea ice to calculate the water content in snow. The geometry structure of antenna contains exponential tapered slot for flare notch, inclined groove and a rectangular cavity. Single element dimensioned as 104mmX12.3mm is made on thin aluminum material of 3.97mm thickness. Authors designed this antenna array system based on Kindt and Pickles [13] flare notch array antenna as it can be reliably produced and mechanically strong to fuse into systems. The entire antenna system operating for ultra-wide bandwidth of 2-18GHz is fabricated at once by precise aluminum machining and an extended Teflon SMP connector is used to feed the antenna array. The cost and array performance are adjusted by producing a finite 10X10 array prototype elements sized 125 mm × 125 mm × 104 mm and is integrated into airborne snow radar, measured results conclude that array is capable of providing 7-25dBi gain and is able to scan area of 30 degrees.

In paper [15], authors designed a dual polarized wideband Vivaldi antenna system having passive cooling capability for compact enclosure deployments like telecommunication 5G networks and sensing applications is designed. The three notable layers of proposed system are the antenna structure, multi-layer PCB and active components to feed. The designed Vivaldi antenna array having simple single-element structure with integrated coaxial feed able to operate in 29-35GHz in Ka band. The 8X8 array fabricated from copper material by conventional milling and electric discharge machining (EDM) wire cutting is able to produce 90% radiation efficiency as no dielectrics are used and do not suffer from surface waves making it more suitable candidate for mm-wave networks. The fully metallic antenna element of size 9.9mmX3.8mm have beam steering up to 60degrees without worsening polarization. The PCB made of Rogers RO4350B is fed to ground plane of antenna array of thickness 2.3mm, the miniaturized radiating elements and integrated coaxial feed will let the antenna array to embed straight on PCB through surface mount technology. Authors claim that if integrated circuits are realized on PCB following the antenna array, the metal structure of antenna array can be used as heat sink to cool. The impedance matching of the element is altered by mutual coupling generated between elements due to their close proximity nature. The authors were able to achieve their objective of designing a compact flared-notch antenna for phased array applications which can easily mounted on PCB board. The resultant 8X8 array antenna shows below -10dB active reflection coefficients for the whole Ka band, 3dB scan loss in elementary planes in 60-degree range and scan loss of less than 3dB in the diagonal planes.

In paper [16], authors designed and manufactured an ultrawide band tapered slot Vivaldi antenna for base station pattern diversity applications, transponder devices and monopulse systems. The designed diversity antenna when used on transmitter and receiver sections is able to offer durable communication system by presenting new channels as it boosts the capacity of wireless links. Authors designed the antenna system by uniting the 2 contiguous tapered slots at 29-degree rotation angle. The dual tapered slot radiating structure having single circular slot at the beginning of taper width is fabricated on Rogers 5880 substrate due to its mechanical flexibility. The mutual coupling of antenna system is lowered by including a rectangular cut to enhance isolation between them. The microstrip line fed diversity radiator downsized by removing unwanted areas when united is ideal for base station applications as it covers wide operational band from 0.7-2.7GHz which is mostly cellular, LTE frequency. The common aperture diversity radiator provides gain of 4-8dBi, with 80% radiation efficiency. As the two tapered elements are combined, the electrical length of shared metal edge is increased leading to decrease in initial working frequency. The fabricated antenna is tested for in-phase and out-phase cases is able to produce end fire radiation with low side lobes. Both simulation and measured results show that radiator provides good diversity over the full frequency range. Authors used a 180-degree hybrid coupler having frequency range from 1-2GHz which can give 3dB in-phase out-phase outputs as feeding network with a rectangular waveguide operating 0.96-1.5GHz as a testing probe to check the pattern diversity performance of antenna. The diversity radiator was able to cover GPS frequency bands and the beam produced can be tilted upwards or downwards is a good candidate for base station applications, it can also be used for monopulse applications because of its pattern diversity feature.

In paper [17], authors designed an edge cut square-shaped MIMO antenna system working at 5G, WLAN bands which can be used in access points, wireless routers and WIFI applications. The 104mmX104mmX0.51mm MIMO antenna system design comprises of 4 dual-band monopole antennas and four wideband tapered slot antennas manufactured on Rogers-5880 substrate. Authors initially designed 4 monopole antennas operating for 2.4-2.6GHz located on each side of square, mutual coupling produced due to least distance between them is mitigated by including a rectangular slot later modified as a tapered slot ending with circular stub to enhance isolation. As the width/length of tapered slot and diameter of stub increases the isolation also increases making no impact on operating bandwidth of monopole antenna. Authors state that optimized dual functioned tapered slot can be used as decoupling structure at 2.4GHz and as an end fire tapered slot antenna at 28GHz.The compact MIMO antenna for future wireless communication systems covers two low frequency bands at WLAN 2.4-5.32GHz, 4G LTE at 2.6GHz and high frequency band 5G at 24-28GHz with 85% radiation efficiency. The system achieved overall gain of 5-11dBi at their operating bands. This miniaturized MIMO antenna system because of its defected ground structure acting as band stop filter for high frequencies is able to have 16dB measured isolation and less than 0.16 maximum envelope correlation which is well suitable for compact wireless devices. Simulated and measured results of this proposed multiband compact 8-port structure confirm that it is a suitable antenna system for mm-band applications as it meets MIMO specifications.

In paper [18], a compact shared aperture dual polarized antenna system having four Vivaldi elements for orthogonal polarization is designed and fabricated. The developed compact antenna system with 40dB port isolation is for ground penetrating radar (GPR) applications having lower operating frequency. This antenna being a vital element of GPR system operating at ultrawideband 0.4-4GHz can provide high penetration depth and image resolution. The single aluminum tapered slot element of size 210mmX210mmX150mm is fabricated on F4BTM-2 substrate. The horn shape Vivaldi antenna system is achieved by connecting four Vivaldi edges with silicone adhesive paste and assembled on reflector made of F4B material to enhance physical support. The novel shared aperture configuration with slant configuration of Vivaldi elements using square loop reflector forms the entire antenna system. This low dispersed antenna system with high gained low frequency is achieved by applying a thin square metallic loop as reflector with improved directivity by unique slant arrangement of elements. The two parallel elements are excited at once for one polarization, other two for orthogonal polarization and are fed by a refined microstrip-slot balun. The authors performed a realistic GPR measurement by burying a metal rebar at 9cm in a highly conductive soil, with good impedance matching and high gain of 4-12dBi the dual polarized antenna system was able to detect making it a suitable candidate for GPR applications. Measured and simulated results confirm this compact antenna system is able to attain a broad bandwidth of 164% with excellent polarization quality.

3.COMPARISON TABLE

A number of critical factors affect an antenna's performance at mm-Wave and Sub-6 GHz frequencies. Because Sub-6 GHz antennas operate at longer wavelengths, their sizes are often bigger than those of mm-Wave antennas. The choice of material is important: mm-Wave demands low-loss materials for stability at high frequencies, while Sub-6 GHz frequently uses common materials like copper. While mm-Wave antennas have smaller fractional bandwidth (FBW) for high-frequency accuracy, Sub-6 GHz tends to have greater FBW. Due to larger losses in mm-Wave, Sub-6 GHz antennas usually have higher efficiency. A comparison study carried on various parameters like size, material, efficiency, etc of latest 5G Vivaldi antennas systems is tabulated in Table 1.

Table-1: Comparison Table

Ref.	Size in mm^3	Sub-6 GHz &mm-Wave	Material	Gain (dBi)	FBW	Efficiency	Ports/Size	Polarization
[4]	20X20X29	6 - 11	*Al. & Ti*	5.70	0.56	94.52%	Single port	Unidirectional
[5]	530X400X2.5	2 - 50	*Al.*	4 - 12	1.86	N/A	Single port	Unidirectional
[6]	125X30X4.2	2 - 6	*Al.*	19-20	1	N/A	Array	Dual polarization
[7]	30X10X4	16 - 18	*Al.*	15-24	1	91%	Array	Dual polarization
[8]	112X18X6	1 - 7	*Al.*	5	1.5	90%	Array	Bidirectional
[9]	45X35X0.79	3.06 - 26.25	Rogers-5880	10.2	1.5	90%	Single port	Unidirectional
[10]	75X25X0.254	3.4- 4.4 25-32	Rogers-5880	4 8	0.25 0.24	N/A	Multi-port	Unidirectional
[11]	140X24XN/A	4.6 - 18	*Al.*	3.4 8.7	1.18	N/A	Array	Unidirectional
[12]	15X15X19	2 - 10	*Al-6061*	N/A	1.33	90%	Array	Dual polarization
[13]	131X18X2.5	0.5-9	*Al-6061*	5	1.789	97%	Array	Orthogonal
[14]	104X12.3X3.97	2 - 18	*Al.*	7.3 - 25.8	1.6	N/A	Array	Dual polarization
[15]	9.9X3.8XN/A	29-35	Copper	N/A	0.187	90%	Array	Dual polarization
[16]	232X145X0.58	0.7-2.7	Rogers-5880	4.05 - 8.3	1.176	80%	Single port	Uniform
[17]	104X104X0.51	2.4- 2.6 24 - 28	Rogers-5880	11	0,059 0.153	85%	Multi-port	Unidirectional
[18]	210X210X150	0.4 - 4	*Al.*	4 - 12	1.636	82%	Multi-port	Orthogonal

*Al.**=Aluminum, *Ti.* *=Titanium, *FBW**=fractional bandwidth.

4. CONCLUSION

The key findings from my review includes various existing Vivaldi antenna system designs and their fabrication methods. The basic mechanism along with design evolution with its advantages is presented in this paper. It is also explained in literature survey how the different kind of slots and corrugations improve antenna performance and reduce the leakage in an array system. Vivaldi antennas are suitable candidates for 5G networks is highlighted in this review.

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