A Unique Technique to Improve the Performance of Antipodal Vivaldi Antenna for Microwave Imaging Application

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Abstract. A highly directional Ultra-wideband (UWB) Vivaldi antenna is offered for the study of microwave imaging utilization and radar based technique. In this paper, a novel Vivaldi antenna is designed which improve the directivity, gain and bandwidth parameters of the antenna. Initially the desired performance is achieved by making some changing in the exponential tapered structure. Again some modifications are made in the top of the patch by adding some corrugations in the flaring section, so better performance improvement is obtained in the value of directivity, low frequency of operation, bandwidth and gain. The operating frequency of the tapered Vivaldi structure is 1.45GHz in the lower cut-off frequency whereas the upper cut-off frequency is 9.8GHz. The proposed corrugated Vivaldi antenna is fabricated using FR4 substrate prototype of the modified antenna is fabricated and experimentally studied as well.

Keywords: Machine Learning, Image classification, Security analysis, Security of frameworks.

1. Introduction

The Vivaldi types of antenna is variety of slot antenna with tapering which is operating under the rules of travelling wave types of antennas. The basic secret behind the exponential tapered profile is enlarged bandwidth and pencil beam radiation pattern can be easily achieved. The various applications of Vivaldi antennas are identification of tumor cells [1], weapons detection in hidden place of on-body structure [2], crack detection [3], radar applications [4] and so many different applications are possible in the exclusive performance of the Vivaldi antenna.

In the extra-large bandwidth used systems, wideband antennas [11] are normally used which is least complex structure, minimum amount of power consumption and profile is so compact. In wideband antenna design there are many different varieties, based on the features like, weight, cost of manufacturing, far-field radiation pattern, simplicity and integration of system. The main challenging features of the Vivaldi types of antenna design is directivity over a wide range of frequency and radiation pattern stability .In the end-fire direction the maximum radiation intensity can be achieved when the phase of the current signal which has 180° phase shift. If this particular condition is achieved, then enlarged operating bandwidth of the antenna can be obtained.

In many of the recent research work, many techniques are proposed to improve the performance of the radiation in the different types of Vivaldi antennas. The enhanced performance can be achieved by adding of a parasitic ellipse in antipodal Vivaldi structure [6], antipodal Vivaldi structure with tapered slot edge [7], antipodal Vivaldi structure with parasitic element at the tapered edge [8], antipodal Vivaldi structure with uniform corrugation [9], tapered slot antenna [3], Vivaldi antenna with tapered slot [12], vivaldi antenna along with dielectric cover [13 ], Dual slot vivaldi antenna [14]
etc., in the flare sections in order to propagate the energy in the direction of end-fire way. The above said techniques increase the design, fabrication complexity and broad radiation pattern with many side lobes.

With these information, our team proposed a novel technique in order to improve the performance of the Vivaldi antenna by introduction of a corrugation in the flare aperture which is shown in fig.2. Experimental result shows that, by introducing the parasitic ellipse structure increases the directivity, gain and radiation pattern with reduce the side lobes and expanding the lower frequency of operations. The entire antenna structure of the antenna is 110 x 98 x 1.6mm³ which includes the feeding line and exponentially tapered patch. The presented corrugated Vivaldi antenna shows an improved performance while compared to the other types of Vivaldi antennas.

2. Antenna Design

This section explains about the Ultra Wide Band frequency coverage from 1.45GHz to 9.8GHz due to the development of antipodal Vivaldi structure with corrugations. The proposed corrugated Vivaldi antenna is simulated using the CST MWS [10] which is 3D simulation software for electromagnetic analysis.

2.1 Antenna Configuration

Figure 1 and figure 2 illustrate the geometry configuration of the proposed antenna structure without and with corrugations. Without and with corrugations Vivaldi antennas are designed with a thickness of 1.6 mm using the FR4 substrate material having the permittivity \( \varepsilon_r = 4.2 \). The designed antennas have feed line, and radiating structure is tapered. Radiating structure in the Vivaldi antenna is exponential tapered in shape, due to this structure the radiation occurs through the axis of the tapering edges. Due to the gradual curvature of the radiating construction, unlimited bandwidth can be achieved [5]. The width of the Microstrip feedline is set to be 1.9 mm in order to match the 50 \( \Omega \) coaxial line. The tapered structure of the antenna is achieved by the following equation (1),

\[
y(x) = cx^k
\]

where, \( c \) is a constant and \( k \) represents the opening rate which is given by,

\[
C = \frac{S}{2}
\]

\[
k = \frac{1}{L_a} \ln \left( \frac{W_a}{S} \right)
\]

where, \( L_a \) represents aperture length, \( W_a \) represents aperture width and \( S \) represents the width of slot at origin.
The gain of the antenna can be improved by using tapered corrugations in addition to the decrease factor ($f_t$) is added at the flare angle edge of the Vivaldi antenna structure. The corrugation structure is introduced in the ground by introducing many cutting in the form of rectangular slots with different length. The slot width and distance of separation between the rectangular slots are same whereas, the length of the rectangular slot reduces as a factor of $f_t$. The corrugations in the ground plane act as resistive loading, this is due to the fact that maximum fields retained in the slot area. Due to the effect of corrugations, the gain parameter of the proposed Vivaldi antenna increased in the direction of the end-field.

The optimized value of the proposed structure of Vivaldi antennas are given in Table I.

**TABLE I. Proposed Vivaldi antenna parameters**

| Parameter                              | Dimensions (mm) |
|----------------------------------------|-----------------|
| $L$                                     | 98              |
| $W$                                     | 110             |
| $L_f$                                   | 1.6             |
| $W_f$                                   | 4.5             |
| Patch Arc (A3,A4 counter clockwise)     | $81^0$ and $60^0$ |
| $L_p$                                   | 49              |
| $L_g$                                   | 49              |
| $W_g$                                   | 55              |
| Length of the grating                   | 0.5             |
| Ground Arc (A1, A2 in clockwise)        | $81^0$ and $60^0$ |

**Figure 1.** Geometry of the antenna without corrugation (a) front vision and (b) back vision

**Figure 2.** Geometry of the antenna with corrugation (a) Front vision and (b) Back vision
2.2 Fabrication of proposed antenna

The picture of the fabricated Proposed Vivaldi antenna is shown in figure 3. The antenna is fabricated at a height of 1.6mm FR4 substrate with dielectric constant ($\varepsilon_r = 4.2$). A female SMA connector is soldered at the edge of the microstrip fed line. The fabricated Vivaldi antenna is measured in Agilent E5071C VNA with the highest frequency set is 10 GHz.

![Figure3. Photographs of proposed Vivaldi antenna](image)

3. Results and Discussions

This section explains, the performance of the proposed Vivaldi antenna with corrugation and without corrugation is verified using simulation software. Different parameters like reflection coefficient, radiation pattern, E-field, H-field and gain from the 3D radiation pattern are analyzed in the following section.

3.1 Reflection coefficient

The bandwidth of the Vivaldi antenna without grating ranges from 1.32GHz to 8.72GHz whereas the Vivaldi antenna with grating has the bandwidth ranges from 1.45GHz to 9.82GHz. The bandwidth of the antenna is shown in figure 4. The result shows that Vivaldi antenna with grating shows better performance compared to the antenna without grating. Due to high bandwidth the proposed Vivaldi antenna with grating can be used for microwave imaging application. Since low frequency range is used for deep penetration and high frequency range used for high resolution. So the proposed Vivaldi antenna is suitable for identifying the embedded object in the human body.
3.2 Radiation pattern

The radiation pattern of the proposed Vivaldi antenna is shown in the figure 5. The radiation pattern is highly directional, so the proposed antenna is used for microwave imaging purpose. At the frequency of 3.6GHz in far field range, directivity is 8.423dBi and the gain is 6.61dBi.

3.3 E-Field Pattern

Antenna radiate two different types of field like E-field and H–field. The plot of principal E-field component is shown in the figure 6. This is obtained by mapping the field component over different angles (θ, φ), which firm 3D plot. The dominant mode of the E-filed at the frequency of 3.6GHz is shown in fig. 6. The main lobe magnitude of the Vivaldi antenna is 6.28dB at the angle of 146°. The angular width is 32.5° having minimum side lobe levels -1.1dB.

3.4 H-Field Pattern

The plot of principal E-field component is shown in the figure 7. The H-field wrap around the microstrip antenna. H-field pattern is related to the movement of free charge carriers. The H-field is perpendicular to the direction of E-field. Both are orthogonal to each other.
3.5 Measured Result

The proposed Vivaldi antenna is fabricated using FR4 substrate material which has the dielectric constant of 4.3. SMA connector is connected at the feeding point of the antenna in order to give input to the antenna. When an input is given, the antenna radiate the microwave signal. The radiated microwave signal is measured in the far field range. The obtained bandwidth of the proposed antenna during measurement ranges from 1.45GHz to 10GHz range is shown in figure 8. The difference in bandwidth for simulation and measured value is due to some external noise, impedance mismatch between the feed point and connector.
4. Conclusion

The proposed corrugated Vivaldi antenna with ultra-wideband characteristic for the use of a microwave imaging system has been developed. The reported antennas face the impedance bandwidth of 1.45GHz to 9.82GHz. The VSWR is less than 2 over the entire range of UWB band. Among the two different proposed Vivaldi antennas, with grating antenna is showing better performance than without gratings. The measured result is in congruence with the simulated result of the proposed antenna.

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