An Ultra Wideband Wide Beam Strip line Fed Taper Slot Antenna for Active Phased Array Jammer

Gaurav Dwivedi

Abstract – Multi octave bandwidth, wide scanning angle, small interelement spacing and mutual coupling between elements are some of the requirements of Active Phased Array (APA) used for EW Jammer applications. Taper Slot Antenna (TSA) represents a class of antenna elements which is capable enough to meet all these requirements. Keeping the properties of TSA in mind, a Strip line fed Taper Slot Antenna (TSA) has been designed and fabricated to serve as an Antenna element over a large bandwidth from 6 to 18 GHz for an Active Phased Array (APA). This Antenna Element exhibits some attractive features like wide beam width over a wide bandwidth, Gain for a high ERP, compactness and less mutual coupling. The simulated as well as the measured radiation pattern and VSWR have been presented and discussed in this paper. The Antenna element has been designed and optimized in CST Microwave.

Keywords – Taper Slot Antenna (TSA), Beam width, Strip line, Active Phased Array (APA), ECM.

I. INTRODUCTION

The TSA family belongs to the group of end fire traveling wave antennas and the printed antennas from view point of its appearance and physical characteristics ([1] - [6]). Traveling wave antennas have demonstrated broad bandwidth, relatively high gain, and symmetrical *E*- and *H*-plane beam patterns. TSA consists of a feed line, which is usually micro strip or strip line, transition from the feed line to the slot line or balanced strip line and the radiating structure. Radiating structure is usually exponentially tapered but examples of linear, parabolic, hyperbolic or elliptical curves are also available. The continuous scaling and gradual curvature of the radiating structure ensures theoretically unlimited bandwidth, which is, in practice, constrained by the taper dimensions. There are three fundamental types of Vivaldi antenna, which can be used as the radiating structure. These types are Tapered Slot Vivaldi antenna, Antipodal Vivaldi Antenna and Balanced Antipodal Vivaldi Antenna. This paper describes a unique TSA Element designed for the Active Phased Array based EW Jammer .This is a new ECM concept used for the identification and jamming of threats with a precise direction.

The frequency coverage of APA is 6-18GHz and the angular coverage is 120^0 .The APA should also maintain a high Effective Radiated Power (ERP) during the beam scanning as it is being used as a Jammer. Also the Interelement spacing between the Array should be less than λ/2 at the highest Frequency of operation.

Hence the Antenna Elements used for the APA should also have the same features like wide bandwidth [3], wide beam width and relatively Higher Gain to achieve the desired ERP. Also the thickness of the Antenna Element also meets the Interelement spacing criteria. Thus TSA becomes the suitable element for this application. The Design Goal for Element is to achieve the Bandwidth of 6-18GHz, 3dB Beam width of 120^0 in the H-Plane, Minimum Gain of 3dB and VSWR of 2:1.

II. VIVALDI ELEMENT

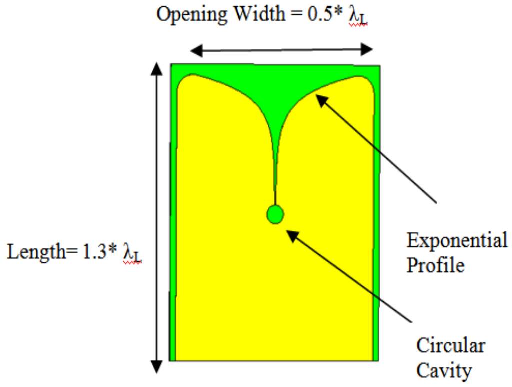

Fig.1 Model of Strip line Fed Vivaldi Antenna

There are two types of transitions in the TSA. One is the strip line to slot line transition and other is the slot line to free space transition. Both transitions have their effect on the bandwidth and the return loss of the TSA. The gradual opening of the slot line depends upon the selected taper profile and it provides a matching between slotline to free space transition and thus minimizes the reflection at the transition region. Hence an exponentially taper profile has been chosen for the Taper Slot Antenna Element (as shown in Fig 1) to provide broad bandwidth as well as Beam width.

The strip line to slot line transition governs the bandwidth of a TSA, hence in order to get a bandwidth of 6-18GHz, a strip line feeding technique has been employed as shown in Fig 2.

To achieve the beam width of 120° in azimuth plane, the design parameters like length, width, thickness of the substrate, slot line width, and taper profile of the TSA have been optimized.

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* Correspondence Author (s)
Gaurav Dwivedi, Electronics & Communication Department, Gyan Vihar School of Engineering. & Technology, Jaipur,, India.

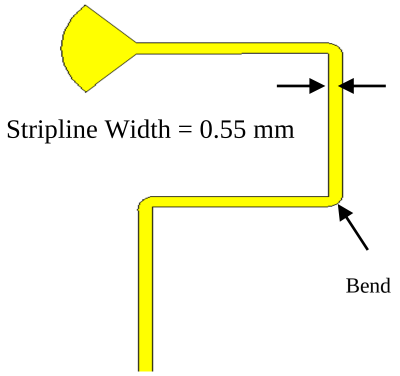

Fig.2 Model of Strip line feed.

III. DESIGN PARAMETRS & DETAILS

The relationship between TSA directive gain and length can be given as:

$$D = 10\log(10L/\lambda_0) \quad (1)$$

Where

λ_0 is the free space wavelength at any frequency of operation.

L = Length of the TSA

Thus for a high gain TSA, length is generally taken as 2 to 3 times of the wavelength of the lowest frequency of operation. But, for a wide beam TSA, the length has been chosen and optimized to almost one wavelength. The optimized length is 1.3* λ_L where λ_L is the free space wavelength at lowest frequency of operation.

For efficient transition from slot line to free space, Opening width of the TSA should be greater than 0.5* λ_L [2]. Therefore, optimized Opening width for TSA is chosen as 0.5* λ_L at 6 GHz and curved edges are provided with a radius of 4 mm. RT/Droid 5880 is chosen as substrate and thickness of the TSA (shown in Fig 1) is taken as 40 mil. The slot line width is taken as 0.25 mm for ease in fabrication.

IV. EQUATION OF THE FLARE

The Beam width and the VSWR of a TSA depend upon the type of flare provided for the widening of the slot line. The flare can be exponential, linear, parabolic or some other equation based curve. The TSA flare is designed as

$$y = [y_0 + \{(y_1 - y_0)*(e^{Rx}-1)/(e^{Rx1}-1)\}] \quad (2)$$

Where

R = taper factor = 0.22

y_0, y_1 and x_1 are the coordinates of initial and final points of the flare. The slot flare is selected as an exponential profile and taper factor is optimized for wide 3-dB beam width for H-plane as compared to other profiles of TSA. The flare is provided on the both faces of the substrate which makes the TSA a dual polarized Antenna Element.

V. FEED PARAMETERS AND DETAILS

The Feeding technique plays an important role in impedance matching. Ultra wideband performance of a TSA depends upon the transition from feed to slot line and slot line to free space. Hence a large bandwidth can be obtained by proper impedance match at both the feed transition (the transition from the feed point of the antenna to the slot line) and the slot termination (the transition from the slot line of a TSA to free space). Various techniques have been developed for efficient coupling of field waves from the input to the slot line. Some of the commonly used techniques are micro strip, coaxial, strip line and coplanar waveguide feeding. In this paper a strip line feeding technique has been presented with a radial stub to give better matching over 6-18 GHz band [4]. The designed strip line with radial stub is shown in Fig 2.

The strip line has a constant width of 0.55 mm for efficient transition from strip line to slot line. Simple bends are provided to feed the structure through the ground plane as shown in the Fig 2. For a broadband transition, a radial stub is provided at the end of strip line as a virtual short and a circular cavity is provided for the slot line as a virtual open [10] .The radius of the radial stub must be $\lambda_m/4$ at the center frequency where λ_m is the guide wavelength in Micro strip line and the angle is generally kept greater than 50^0. After optimization the radius and angle are selected as 3.2 mm and 90^0 respectively. The diameter for circular cavity is generally selected as $\lambda_s/4$ where λ_s is the guide wavelength in Slot line. In this design a circular cavity is used for TSA, as radial strip line stub and circular cavity provides a better return loss of 10 dB over a large bandwidth 2.8 to 18.8 GHz [7]. The radius for circular cavity is found to be 2.1 mm after optimization.

VI. RADIATING ELEMENT REALISATION AND PERFORMANCE

An experimental model of the TSA element has been fabricated on 40 mil RT/Droid 5880 substrate to verify its performance. Fig 3 and Fig 4 shows the simulated and measured VSWR of the TSA element respectively. Fig 5 & 6 show the H-plane beam width of the TSA at 6 & 18 GHz respectively. E-plane beam width at 6 GHz is shown in Fig. A comparison between simulated and measured 3dB beam width has been presented in Fig. 8.

VII. CONCLUSION

In conclusion, a novel Ultra wideband Tapered Slot Antenna Element with a Strip line Feed has been developed. The Antenna offers a wide H-plane beam width of 120° and E plane beam width of 60° .The Strip line to Slot line Transition provides a better matching over the whole band of operation i.e. 6-18GHz. The measured VSWR is observed to be maximum 2:1 over the entire band. The Antenna also has a Gain of 5 to 8dB over the band. Also the thickness of the Antenna is small enough to meet the inter-element spacing requirement for the Linear Active Phased Array. The Less mutual coupling and easy fabrication are some of its other properties which make it a suitable candidate for the APA based EW Jammer.

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Mr. Gaurav Dwivedi, pursuing M.Tech (Dual Degree) from Suresh Gyan Vihar University, Jaipur, Rajasthan. He completed his graduation in Electronics and Communication Engineering from Gyan Vihar School of Engineering & Technology. Mr. Gaurav Dwivedi, pursuing M.Tech (VLSI) from Gyan Vihar School of Engineering and Technology, Jaipur, Rajasthan. He completed his graduation in Electronics and Communication Engineering from Gyan Vihar School of Engineering & Technology, Jaipur, Rajasthan in year 2012. His areas of interests are Digital Signal Processing, Digital Communication System, Digital Electronics etc.