STUDENT PROJECT

VIVALDI ANTENNAS

Antennas

1. INTRODUCTION

The Vivaldi antenna forms part of a group of antennas called end-fire tapered slot antennas (TSAs). End-fire tapered slot antennas include the constant width (CWSA), linearly tapered (LTSA) and the exponentially tapered (ETSA), also known as a Vivaldi antenna. Performance characteristics of TSAs include: Wideband, medium gain and low sidelobes [Yngvesson et al]. The microstrip-fed Vivaldi antenna is manufactured out of metalized dielectric substrate with an exponentially tapered slot in the metallisation. A circular slotline cavity is connected to the narrow end of the tapered slotline (flare) with a short length of slotline. On the reverse side of the substrate is a microstrip line ending in a broadband radial quarter wave stub. The base of the stub overlaps the slotline close to the circular cavity.

There are several possibilities for feeding a Vivaldi antenna. As in this implementation of the Vivaldi antenna, a microstrip to slotline feed is used when the antenna is manufactured on a dielectric substrate. A microstrip to slotline transition is realised by etching the slotline on one side of a substrate and is crossed at a right angle by a microstrip line on the opposite side of the substrate. The microstrip line is flared to form a radial stub which acts as a wideband, virtual short circuit where the microsrip line and slotline cross. The slotline is extended into a circular cavity to act as a wideband, virtual open circuit. The advantage of this feed method is that both the antenna and its feed (which may also include an impedance matching section) can be etched onto the same substrate. Another way is to solder the outer conductor of a semi-rigid coax on the metal sheet all the way to the slotline between the start of the flare and the cavity. The inner conductor is then taken across the slotline and soldered onto the opposite side. Impedance matching is difficult for this type of feed. In both cases the slotline at the Vivaldi feedpoint is terminated by a circular slotline cavity. The cavity dimensions should be large enough to ensure that the feed is not “short circuited” at the low frequency end of the specified band [Shin et al.].

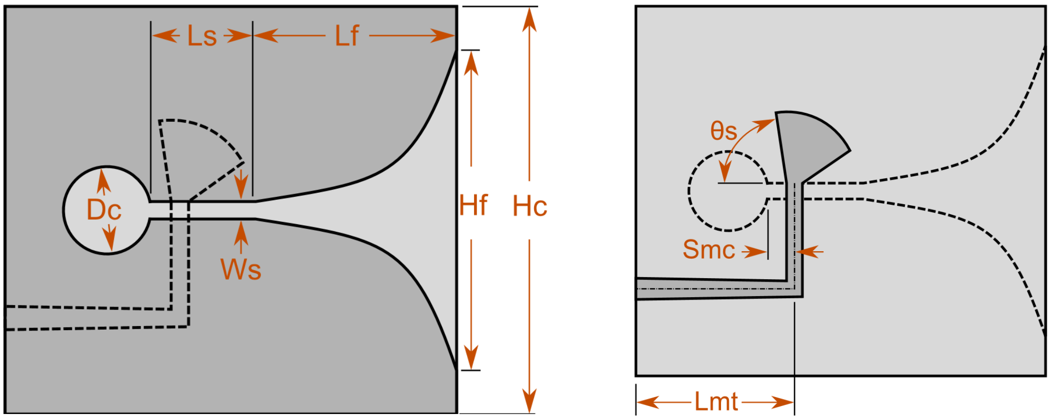

Figure 1. A Vivaldi antenna, (left) top view, and (right) bottom view.

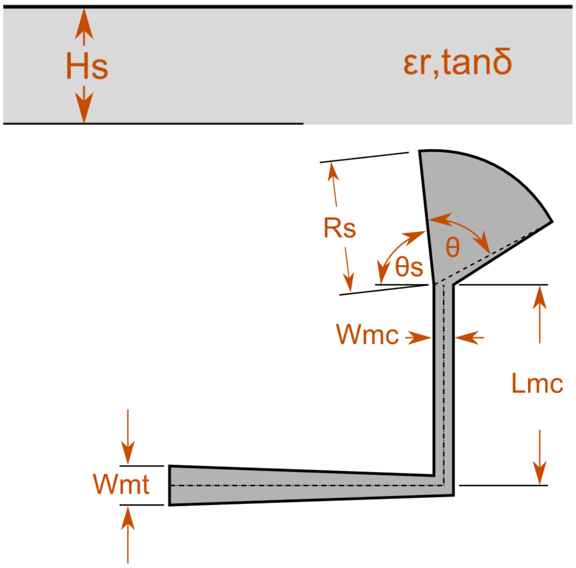

Figure 2. A Vivaldi antenna, (up) side view, and (down) feeding mechanism.

2. DESIGN GUIDELINES

The microstrip line incorporates a tapered section to match the input to 50Ω

- The flare height should be greater or equal to a half-wavelength at the minimum operating frequency.
- The flare length should be greater or equal to a wavelength at the minimum operating frequency.
- The bandwidth can be increased by decreasing the relative permittivity of the substrate.
- The beamwidth decreases and the directivity increases as the flare length is increased.
- To decrease (increase) the input impedance, decrease (increase) the slotline width.
- To decrease (increase) the input impedance, increase (decrease) the relative permittivity.
- The taper factor as defined in [Sutinjo et al.] and [Shin et al.] influences the impedance match and beamwidths.
- The cavity diameter should be approximately a sixth of the effective wavelength of the slotline at 2fmin.
- The stub radius should be approximately a sixth of the effective wavelength of the microstrip line at 2fmin.

3. PROJECT PREPARATION

Given: Target the starting frequency f_0 (e.g. 900 MHz).

Fixed parameters: Substrate parameters ε_r, $tan\delta$, H. The substrate should be FR4. Thickness ≈ 0.8 mm.

Output: $|S_{11}|$, input impedance Z_{in}, radiation efficiency/gain, resonance frequency f_r, radiation pattern.

STEP 1 — CONCEPTUAL UNDERSTANDING

Task:

- Sketch the current path from the microstrip feed to the aperture.
- Explain why Vivaldi is inherently wideband.
- Identify the regions: feed, transition, exponential slot, aperture.

Questions:

- What is the impedance-transformation mechanism in TSA?
- Why is a gradual taper required?
- If the slot shape were abrupt (non-exponential), how would the bandwidth change?

STEP 2 — FEED SECTION (MICROSTRIP-TO-SLOT)

Task:

- Using parameters ($L_f, W_s, L_s, D_c, H_f, H_c$), design the feed that couples microstrip to the slot.
- Choose W_s so that the initial slot impedance is around 100 Ω.
- Select the circular cavity diameter Dc for your band.

Questions:

- What is the role of the circular cavity at the feed?
- What happens to matching if L_f is too short?
- How does W_s influence the lower-edge frequency of the band?

STEP 3 — TAPERED TRANSITION

Task:

- Use parameters L_{mc}, W_{mc}, θ, Rs.
- Implement an exponential taper described by y(x) = c1·exp(a x) + c2.
- Ensure a smooth impedance progression from high (feed) to low (aperture).

Questions:

- Why is an exponential profile commonly chosen?
- If θ_s increases, what happens to bandwidth and matching?
- When would parabolic or linear tapers be acceptable alternatives?

STEP 4 — APERTURE OPTIMIZATION

Task:

- Design the aperture with length L_c and height H_c.
- Increase H_c to extend the low-frequency coverage.
- Sweep H_c and record $|S_{11}|$ and patterns.

Questions:

- How do H_c and Lc affect gain and the lowest usable frequency?
- Can an excessively large H_c distort the radiation pattern?

- What is the link between L_c and pattern stability across frequency?

STEP 5 — BALUN / FEED SYMMETRY CONTROL

Task:

- Because the structure is unbalanced, design a balun (e.g., microstrip-to-slot or Marchand).
- Compare $|S_{11}|$ and radiation with and without the balun.
- Inspect for common-mode currents on the ground/outer conductor.

Questions:

- Why is a balun often necessary in TSA?
- What is the impact of omitting it on matching and pattern?
- How can you detect unwanted currents in simulation?

STEP 6 — BANDWIDTH AND GAIN CHARACTERIZATION

Task:

- Simulate across the frequency band.
- Extract $|S_{11}|$, realized gain, and patterns at three frequencies.
- Determine the $|S_{11}|$ < −10 dB bandwidth.

Questions:

- Compute the fractional bandwidth.
- Why does gain generally increase with frequency?
- When can the "usable radiation bandwidth" be narrower than the matching bandwidth?

STEP 7 — BEAM ANGLE & DIRECTIONALITY

Task:

- Plot radiation patterns vs frequency.
- Measure the main-beam angle at each frequency.
- Check alignment of the beam with the slot axis and adjust θ if needed.

Questions:

- Why can the beam angle drift with frequency?
- How can modifying θ (or the taper) re-center the beam?
- Why is pattern stability important when using TSAs in arrays?

4. FINAL EVALUATION

Acceptance criteria:

$|S_{11}| < -10$ dB across the band, efficiency > 60 %, gain ≥ 6 dBi, dimensions within design limits.

Deliverables: Complete geometry table: (L_f, W_s, L_s, D_c, L_{mc}, W_{mc}, R_s, θ_s, θ, H_f, H_c, L_c). Plots: $|S_{11}|$ vs f, realized gain vs f, and radiation patterns at multiple frequencies. Brief comparison to gradual-impedance theory (exponential taper). Written answers to the questions in each step.

5. REFERENCES

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