Dual-Band Bow-Tie Slot Antenna fed by Coplanar Waveguide

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Abstract

This comprehensive guide explores the innovative design of a dual-band bowtie slot antenna fed by coplanar waveguide (CPW). The antenna incorporates a V-shaped cavity in the ground to enable high-frequency radiation, resulting in dual-band characteristics suitable for applications in aircraft radar and X-band communication. The investigation covers impedance matching, resonance modes, power distribution modeling, and current patterns. Both simulated and experimental results reveal excellent agreement, emphasizing the antenna's potential for dual-band wireless applications.

In this letter, an impedance-matching method to increase bandwidth is presented. It involves the addition of two parasitic patches and a bow-tie slot with curved edges. A dual-band property acquired by combining a notched-band with a wideband antenna is another extremely basic design feature. It is possible to achieve appropriate dual-band impedance bandwidths and suitable radiation characteristics for use in aircraft radar (4200-4400 MHz) and X-band (8-12 GHz) radar operations by carefully choosing the bow-tie slot and V-shaped slot dimensions.

The antenna design exhibits an omnidirectional radiation pattern in the H-plane and a stable radiation pattern in the E-plane, making it a promising candidate for dual-band wireless applications. As the demand for dual-band wireless solutions continues to rise, this antenna's versatile and high-performance characteristics position it as a valuable asset for modern communication and radar systems. Its potential impact on the field of wireless technology is considerable, offering a gateway to seamless and efficient dual-band operations.

Literature Survey

The development of dual-band communication systems has garnered substantial attention due to their vital role in high data transmission, advanced wireless communication, high-sensitivity radar, and imaging applications. Bowtie slot antennas have gained popularity due to their attributes as lightweight, thin-profile, and wide-bandwidth antenna candidates. Coplanar waveguide (CPW) feedlines offer advantages such as wider bandwidth, reduced signal loss at higher frequencies, and compatibility with coplanar designs. However, the majority of bowtie antennas have been limited to single-band operation, making it essential to explore designs that can achieve dual-band performance.

Rafael in, “The bow-tie antenna: Performance limitations and improvements” suggested a method of improving the performance of rounded-edge bow ties that involves putting grooves in the ends of the radiators that are oriented radially. Currents that contribute to damaging radiation in the broadside direction are thus suppressed in the version without grooves. When the rounded-edge bowtie with grooves is simulated in free space, a bandwidth of 97.9% is obtained when the criteria of reflection coefficient magnitude less than 10dB and broadside gain of at least 2dBi are taken into account. This is higher than the bandwidths of the rounded-edge bowties with grooves and those without, which are 92.1% and 85.7%, respectively.

Baljinder in, “A Brief Review on Bowtie Antenna” observed that the potential researchers in this subject have suggested several shape adjustments to enhance bowtie antenna performance. Better return loss, a flatter input impedance, and more stable radiation patterns are all benefits of rounded corners. They also reduce the antenna's surface area. Bow-tie slot antennas are suitable choices because of their greater bandwidth and straightforward planar antenna design. Some methods, including as the use of a tapered metal stub to accomplish impedance matching, inductive coupling, and adjusting slot flare angle to maximize bandwidth, have been suggested to increase the band-width of CPW-fed bow-tie slot antennas.

Jen-Fen Huang in, “CPW-fed bow-tie slot antenna” observed that when the extended angle is zero, the far field is in the broadside direction, and the cross polarization is kept at a low level, the largest bandwidth can be modified by changing the slot width. With a 20° expanded angle, the bow-tie slot antenna can achieve at least 36% bandwidth (VSWR<2). In contrast, the far field has a broader 3 dB beamwidth utilizing a lower slot width in the H-plane than when using a larger slot width. A smaller slot width requires a bigger extended angle to reach the widest bandwidth.

Sung-Hak Kim in, “A Technique for Broad banding the CPW-Fed Bow-Tie Slot Antenna” suggested an approach for 1) optimization of the slot shape, 2) choice of the coplanar waveguide feed line of optimum characteristic impedance, and 3) a proper design of a transition between the coplanar waveguide and the 50-ohm coaxial input.

Over the final third of the slot's length, the end section of the bow-tie slot linearly declines to zero width. 50 degrees has been shown to be the ideal slot angle. The coplanar waveguide supplying the slot is selected to have a characteristic impedance of 130 ohms. A CPW with a 68-ohm characteristic impedance that is linearly tapered to have a 130-ohm characteristic impedance is attached to the input coaxial line. The entire CPW is kept as short as possible while retaining a reflection coefficient of less than -10 dB for the frequency range of 3.5 to 10.0 GHz.

Over 3.5–6.0 GHz, the constructed antenna exhibits good pattern properties. Beyond 8.0 GHz, the radiation pattern has many maxima and minima as well as a maximum position that is skewed in the opposite direction of the feed line. Over 3.5–6.0 GHz, the constructed antenna exhibits a gain of 5.5–7.5 dBi. The ultra-wideband systems and low-power impulse radars are just two examples of the wideband applications that can use the broadband bow-tie slot antenna design that is given in this study. In our upcoming paper, the time-domain performances of the suggested antenna will be covered.

Brief theory and Calculations about the designed antenna

There has been a lot of interest in the development of dual-band communication, which is utilized for high data-rate wireless communications, high-accuracy radars, and imaging systems. Bow-tie slot antennas have drawn more attention as an appealing low profile, light weight, and large bandwidth antenna alternative. Coplanar waveguide (CPW)-fed lines are advantageous because of its coplanar capabilities, wider bandwidth matching, and reduced dispersion at higher frequencies. There have been a number of documented studies for the notched-band characteristic. In order to achieve the appropriate band-notch properties, various slot shapes (such as E-shaped and L-shaped slots) are used.

Bow-tie slot antennas are useful for radar systems and space applications, although the majority of designs can only operate on one frequency.

Impedance Matching

The dual-band bowtie antenna design features a V-shaped cavity etched into the radiating ground, creating a notched frequency band. Additionally, the antenna incorporates a pair of parasitic patches and a bowtie slot with curved edges to enhance impedance matching and broaden the bandwidth. The V-shaped groove serves as the notched element, allowing for dual-band operation.

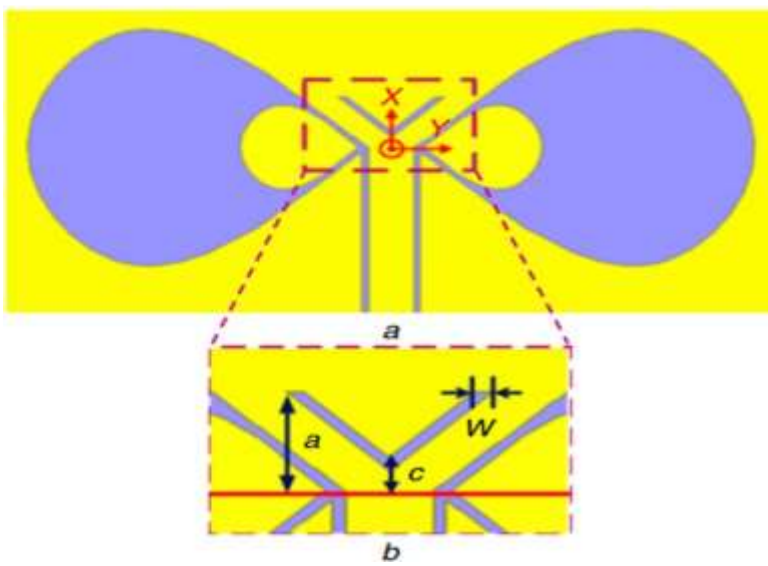
Radiation Pattern

The antenna demonstrates an omnidirectional radiation pattern in the H-plane within the in-band frequency range. In the E-plane, the radiation pattern resembles a dumbbell shape, indicating stable monopole-like radiation characteristics.

Photograph of the proposed antenna

Explanation of the Proposed Antenna

The proposed dual-band bow-tie slot antenna comprises a bow-tie slot, a pair of sector-shaped parasitic elements, and a modified ground plane. The key to achieving dual-band performance lies in the V-shaped groove etched into the radiating ground, which imparts notched frequency bands. This design enables the antenna to cover two essential frequency bands for aircraft radar (4200-4400 MHz) and X-band (8-12 GHz) radar applications. The inclusion of parasitic patches and the modified bowtie slot further improves impedance matching and extends the bandwidth.



a Configuration of proposed dual-band-notch antenna
b Configuration of V-shaped slot structure: a = 7 mm, w = 0.1 mm and c = 1 mm

Fig. a depicts the dual-band bow-tie slot antenna that is being suggested. It is printed on a Taconic RF-35A2 substrate with a thickness of 0.8 mm, a relative permittivity of 3.5, and a tan = 0.0015. It is fed via a 50 CPW feed line. The resonant mode can be moved from a higher frequency to a lower frequency for miniaturization by curving the bow-tie edges. By adding parasitic patches and altering the chamfer angles, the broadband impedance bandwidth can be increased. A V-shaped slit on the radiating ground is used to generate notched bands in order to achieve dual-band performance. The V-shaped slot's configuration is shown in Fig. b. The dimension parameters of a, w, and c have a major role in determining the band-notched performances.

Parts and Characteristics of the Antenna

- The bow-tie slot is the main component of this antenna. It is a bowtie-shaped slot that has been carved out of a conductive surface that resembles two triangular elements joined at their vertices. The slot's form is very important in defining the radiation properties of the antenna.

- This antenna uses a coplanar waveguide (CPW) feed rather than a conventional coaxial or microstrip feed. The design of a CPW transmission line is made simpler and it has some benefits in terms of bandwidth and impedance. CPW has the same advantage as microstrip, in that the signal is carried on an exposed surface trace, on which surface-mount components can be attached.

- This antenna's dual-band functionality is its key characteristic. It is made to effectively transmit and receive signals across two separate frequency bands. In situations when communication or radar systems must function over a variety of frequency ranges, dual-band antennas are advantageous.

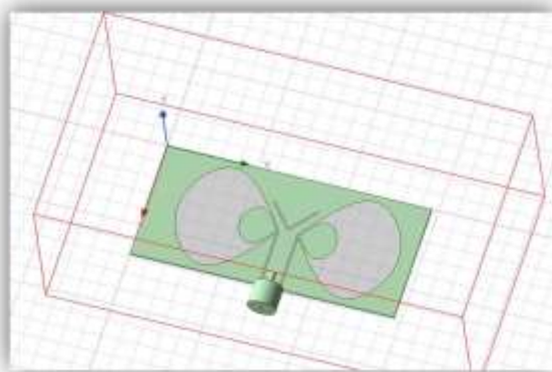
- The radiating ground plane of the antenna has a V-shaped slot etched into it to produce dual-band characteristics. The antenna may operate in two distinct frequency bands without interference thanks to this slot, which serves as a notched band element and regulates the band-notch characteristics.

- The antenna may include a pair of parasitic patches in addition to the bow-tie slot and V-shaped slot. These patches are frequently placed carefully to improve impedance matching, bandwidth, and radiation properties. By changing the antenna's resonance frequencies, the patches can impact how well it performs.

- In order to control the radiation patterns and impedance characteristics, the antenna has a modified ground plane. It is possible to tweak the ground plane shape to get the desired performance in both frequency bands.

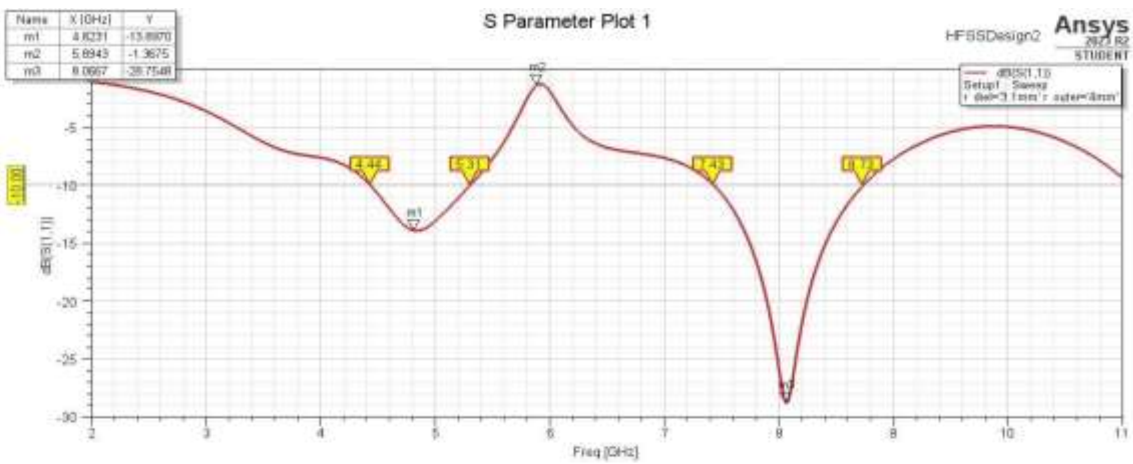
Simulation and Measurement Results

This is our proposed dual-band bow-tie slot antenna fed by a 50Ω CPW feed line.

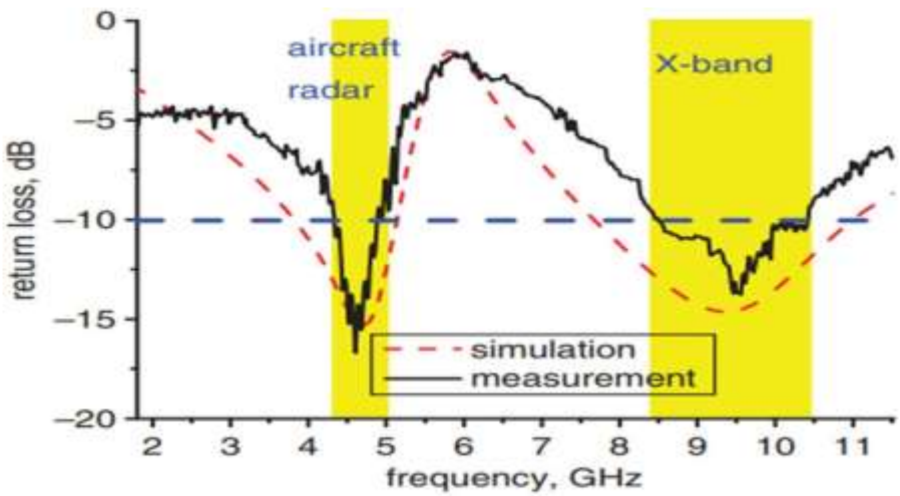


Name	Val...	Unit	Evaluated V...	
r_inner	0.8	mm	0.8mm	Desig
r_diel	3.1	mm	3.1mm	Desig
r_outer	4	mm	4mm	Desig

Return loss characteristics for proposed dual-band bow-tie slot antenna



Simulated



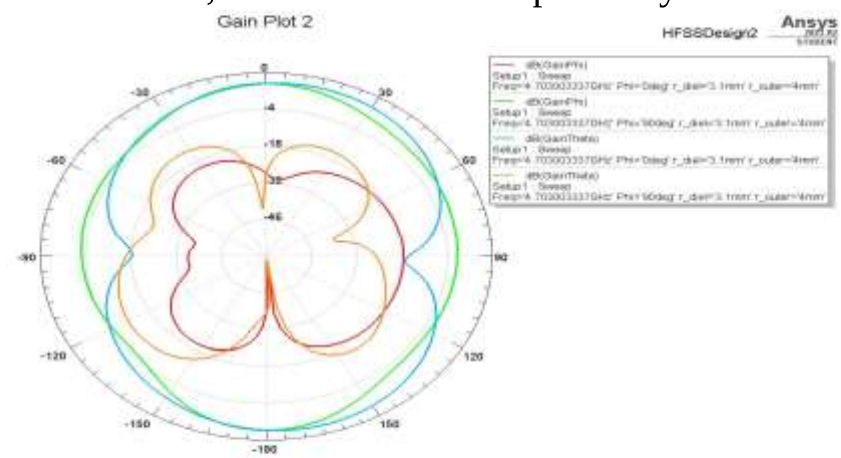
Research Paper

The dual-band antenna given in the research paper provides dual band bandwidths of 4.2–5.15 GHz and 7.5–11.8 GHz for aircraft radar and X-band, respectively. However, the antenna designed by us in Ansys Software provides dual band bandwidths of 4.4–5.31GHz and 7.43–8.73 GHz for aircraft radar and X-band, respectively. The central frequency in the range of 4.4–5.31GHz is 4.823GHz and 8.0667GHz in the range of 7.43–8.73 GHz. Perfect reflection occurs at 5.8943 GHz.

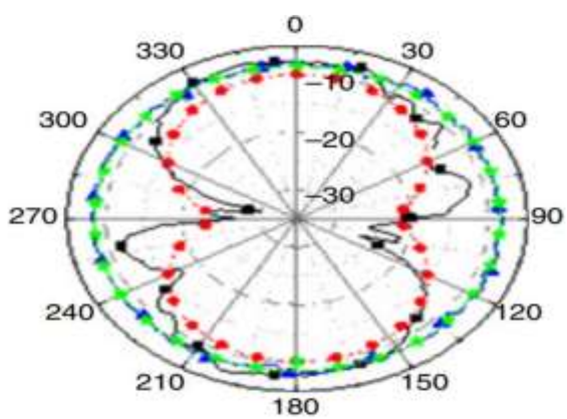
Radiation Patterns in E-plane and H-plane

We have plotted the radiation patterns in both E-plane and H-plane at three different frequencies of 4.7, 5.8 and 10 GHz respectively.

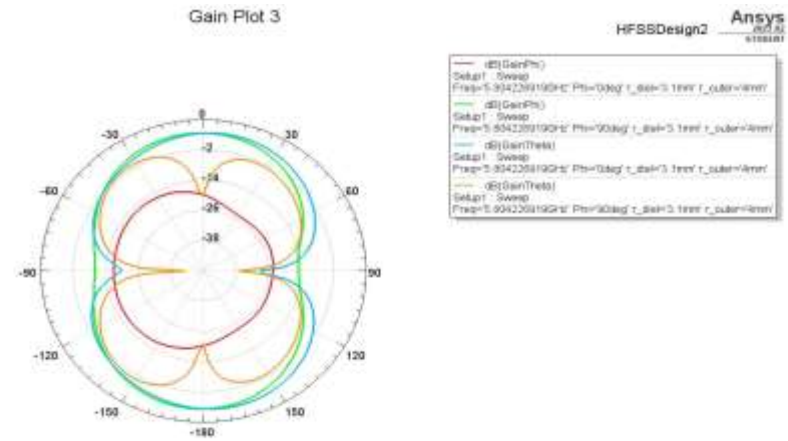
Simulated
Frequency: 4.7GHZ



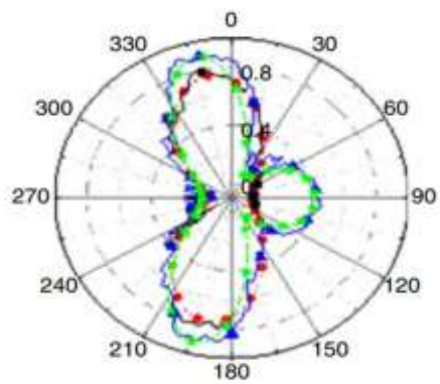
Research Paper
Frequency: 4.7GHz



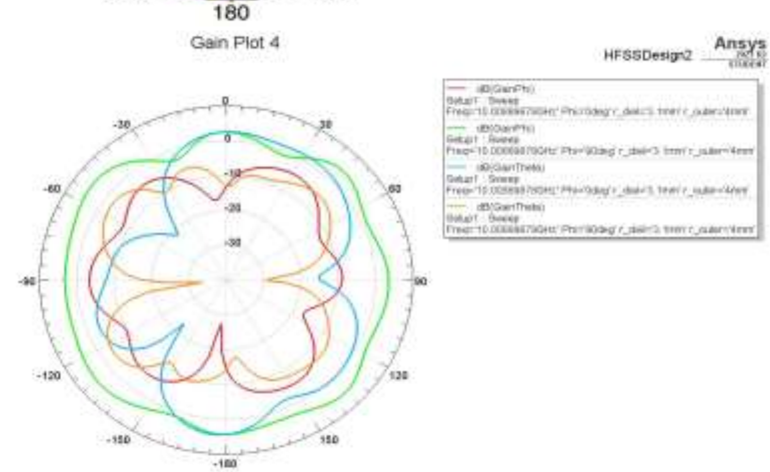
a



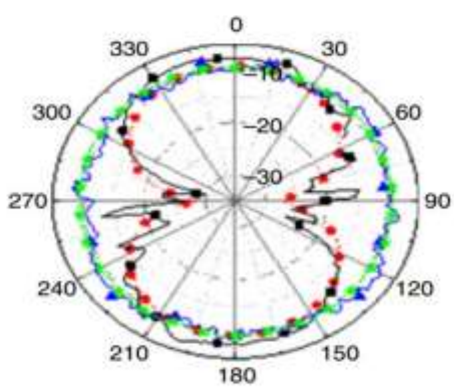
Simulated
Frequency: 5.8GHZ



Research Paper
Frequency: 5.8GHZ



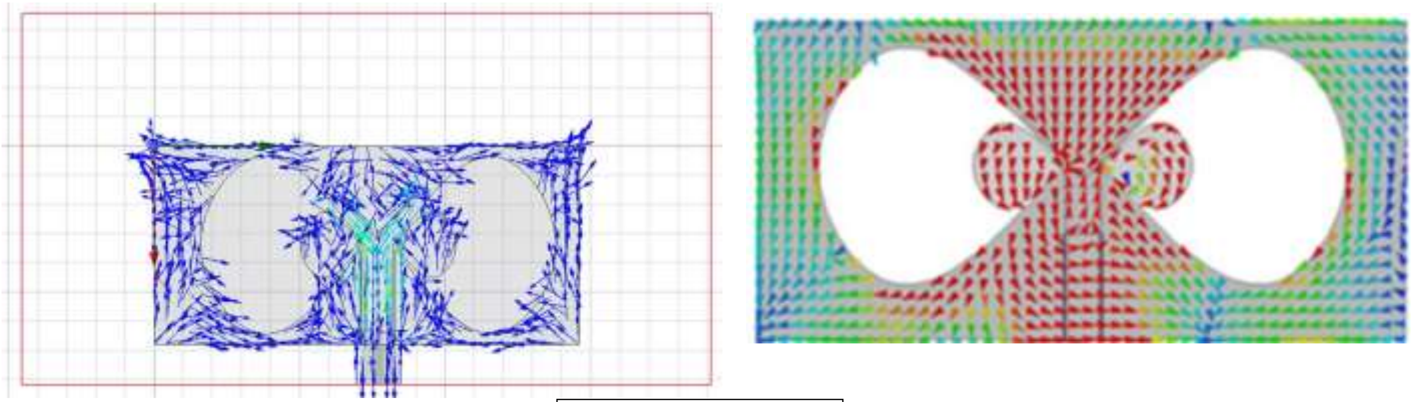
Simulated
Frequency: 10GHZ



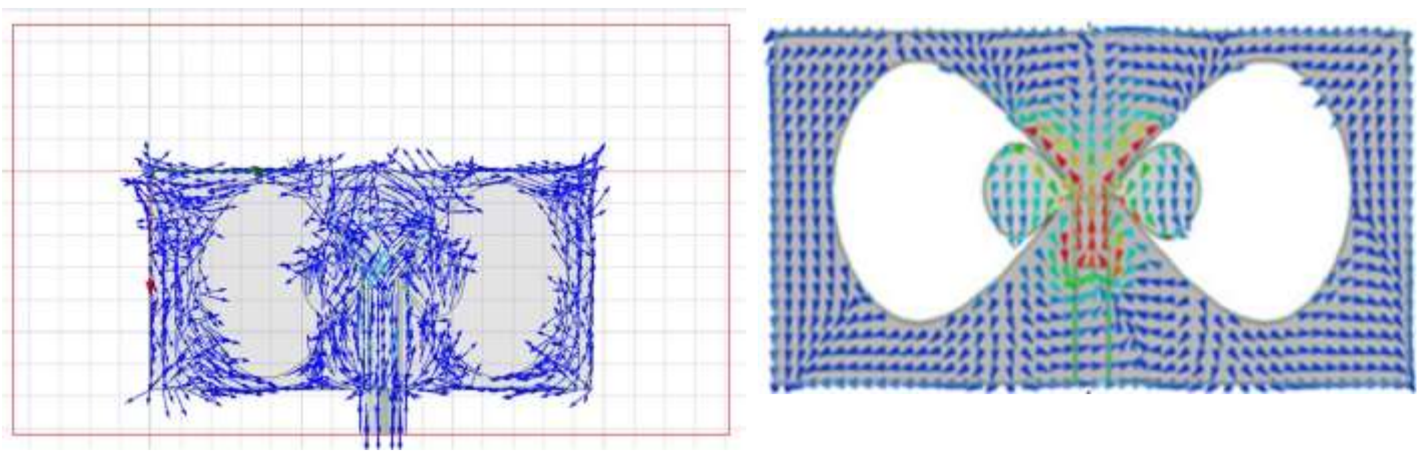
Research Paper
Frequency: 10GHZ

Surface Current Distributions

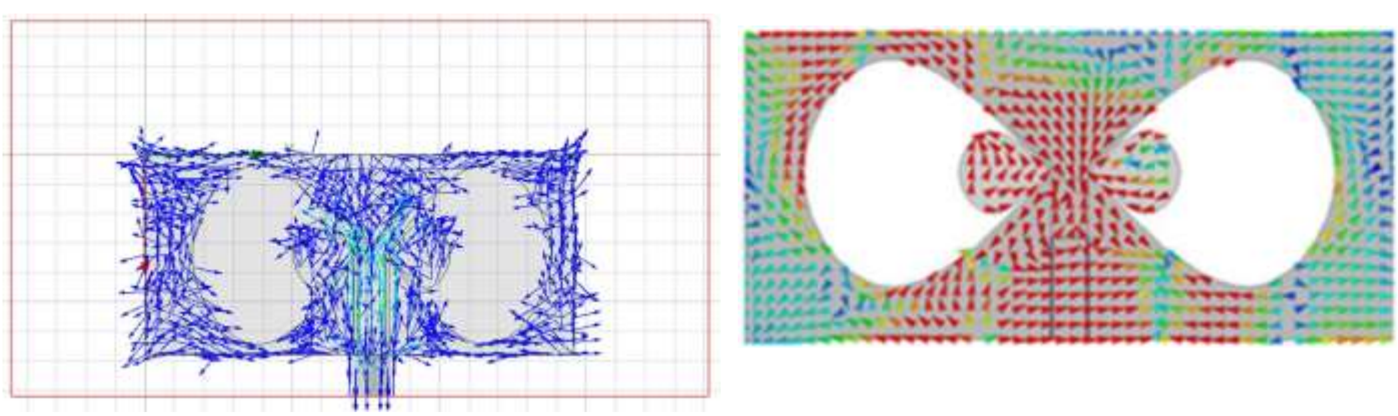
We have simulated surface current distributions at three different frequencies of 4.7, 5.8 and 10 GHz respectively and compared with the surface current distributions given in the research paper assigned to us.



Frequency: 4.7 GHz



Frequency: 5.8 GHz



Frequency: 10 GHz

Conclusion

In conclusion, the CPW-fed dual-band bowtie slot antenna, utilizing a V-shaped design to achieve dual-band performance, proves to be suitable for applications in aircraft radar and X-band communication. The antenna design exhibits an omnidirectional radiation pattern in the H-plane and a stable radiation pattern in the E-plane, making it a promising candidate for dual-band wireless applications.
The antenna designed by us in Ansys Software provides dual band bandwidths of 4.4–5.31GHz and 7.43–8.73 GHz for aircraft radar and X-band, respectively. The E-plane radiations are dumbbell shaped, which shows that this antenna has a stable monopole-like radiation pattern.
Thus, the proposed antenna in the paper is successfully simulated in Ansys Software. This dual band antenna is suitable for a variety of applications in Radio frequency (RF) and wireless communications.

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