A MULTIBAND DESIGN TECHNIQUE FOR PLANAR MICROWAVE APPLICATIONS

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ABSTRACT:

In order to facilitate device migration and updates, wireless communications is making significant development. Therefore, multiband communication systems are becoming more and more popular, and multiband circuits are crucial for the creation of small, inexpensive multiband communication systems. In contemporary wireless communications, antennas are crucial components. The Vivaldi antenna is the most preferred option because of its highly directional nature and straightforward design. There are many different types of antennas used for wireless communication. Because microwave applications require strong gain and performance over a broad frequency range, vivaldi antennas are being employed more frequently. Here, the suggested a scaled-down Vivaldi antenna that utilizes ultra-wideband mirror image concept. A partially modified radiating arm and metallized vias that resemble an electrical wall make up the antenna. By replacing the mirror image current in the radiating arm at its symmetry point, the current produced in the electric wall can produce the Vivaldi form, according to the mirror image theory. The spatial wavelength antenna is scaled down to its original proportions from the Vivaldi antenna's dimensions. The impedance of the corresponding attribute grows due to the exponential cross-side. As a result of the use of multiband microwave circuits in this communication system, the multiband capability is primarily achieved by the hardware.

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I. Introduction

Remote sensing, communication, and heating are frequently used applications in the microwave frequency range. In both household and industrial contexts, microwave heating is now often used. However, the telecommunications industry's demand for the usage of the microwave frequency spectrum is still increasing quickly. The widespread usage of television transmission and satellite technology are both blatant uses of microwave frequencies. Furthermore, it is anticipated that new microwave-based solutions would assist quickly increase the coverage of cellular networks. Accurate design tools are needed because of the recent, rapid development of the utilization of high frequencies. For cost-effective R&D, design techniques that allow "correct first time" forecasts are crucial. The accuracy of the design tools is frequently exchanged for the necessary computing effort. Although existing tools allow for rapid design, they are not precise enough for contemporary applications. A high level of computational power is needed for high precision analytical tools, which are an alternative. Software tools like Linmic and Sonnet, for instance, are available and utilize the findings of more complete electromagnetic analyses [5, 6], but they are constrained by the intrinsic computing effort involved. The needs of designers demand accurate technology that enables interactive designs like straightforward designs.

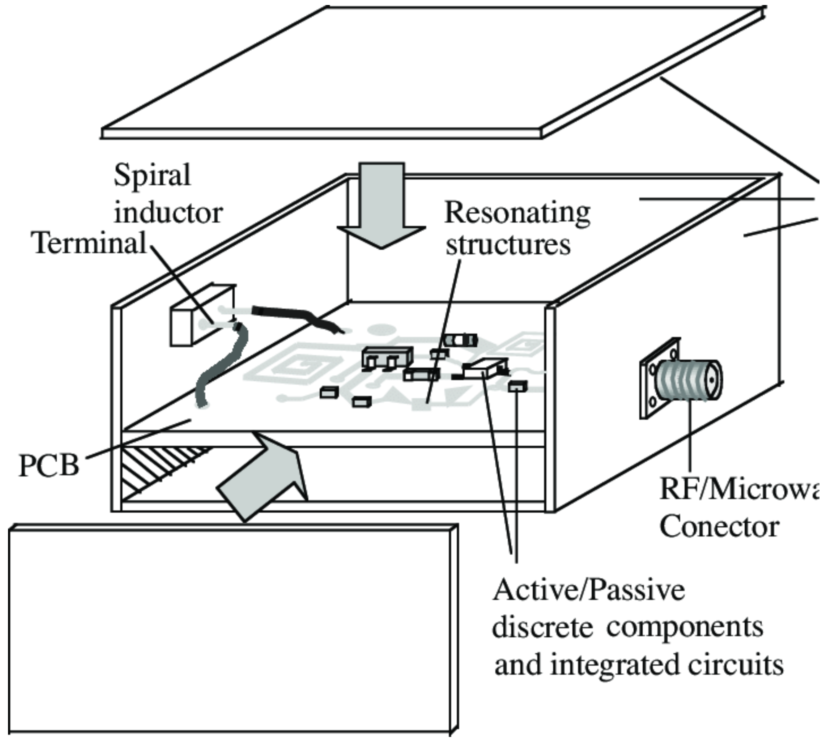

Figure 1:Microwave Circuit[5]

Figure 1 illustrates microwave circuit design. High-speed computers are unable to address this challenge due to the intricacy of the circuits that must be developed and the computational load necessary for accurate simulation. Highly directional antennas and high operating frequencies are necessary for modern wireless communication systems with high data rates and capacities, such as microwave imaging and through-wall detection.With the necessary properties for high frequency applications, tapered slot antennas or Vivaldi antennas are excellent options. The benefit of Vivaldi antennas is that their ability to be produced similarly to printed circuit boards simplifies antenna design. Vivaldi antennas enable applications requiring high frequency and highly directional radiation. It can therefore be applied to microwave imaging applications that demand high precision of the wave's range. High hardware integration devices for these applications need efficient antennas that are small and light.The half-mode approach has been presented as a design principle for the Vivaldi antenna in order to shrink its size without compromising its performance. A half-mode UWB Vivaldi antenna is created in this research for microwave imaging applications.

This is relatively simple and essential when designing microwave integrated circuits and small-scale circuits, but knowing microstrip theory is more challenging. Because the conductive strip is not entirely enclosed by a dielectric, the fundamental mode of propagation is not a pure TEM mode.

II. Literature Survey

In today's wireless communications, antennas are crucial. There are numerous different antennas for wireless communication, but the Vivaldi antenna is preferred because of its high directivity and straightforward design. Migrating to Vivaldi antennas in microwave applications is largely driven by the requirement for high gain and operation over a broad frequency bandwidth range. Circular slots were added to the antenna surface to lessen typical reflections because the researcher is currently working to minimize RCS for military purposes. This does not meet data rate requirements, but it does lower the RCS without losing radiated performance. Circular slots make designing antennas more difficult [1]. To enhance the Vivaldi antenna's data rate, we inserted a dielectric lens around it, although this decreases gain and stimulates higher modes [2]. The radiating element of notchband antennas is enhanced with strips and resonators to resist higher mode excitation and frequency false selectivity. Although the data rate is low in comparison to other antenna designs, this antenna design offers good selectivity [3].

For purposes like locating gaps in matched samples, antipodal designs are particular structures made. To increase antenna gain and radiation, this design minimizes size but necessitates a special slot-edge strategy [4]. A rectangular slit was used in this compact antipodal design to produce high-quality images and obtain radiation characteristics appropriate for imaging applications, as opposed to the AVA-based slit-edge approach, which offers low-loss and is not suitable for microwave imaging of high-loss concrete materials [5]. The antenna must have sufficient gain, a consistent radiation pattern, and a strong directional pattern at both low and high frequencies in order to be shrunk. They adopted a particular design structure of fractal sheets inspired by ferns to achieve the desired results, such as constant radiation pattern and constant data rate [6]. The two sets of eye-shaped slots' special arrangement results in improved unidirectional radiation properties and greater gain at low frequencies, but the impedance bandwidth is not wide enough to span the entire UWB frequency range.

The data rate decreases with increasing frequency [7]. The Vivaldi antenna's radar cross section was reduced using a novel design that involves cutting the antenna's edges. This antenna has backscatter, but it has poor directivity, which leads to slow data rates at low frequencies [8]. Although the dielectric component influences the radiation behavior in the high modes, a balanced antipodal Vivaldi antenna with three layers of copper and ground planes on the two outer layers was employed to make up for the antenna's weak directivity. yields [9].

In this study, a microwave application-specific antipodal Vivaldi antenna with metal vias is described. The suggested antenna's high gain, wide bandwidth, and exceptional antenna characteristics make it appropriate for imaging applications and tumor diagnosis. The many metal vias in this antenna strengthen the antenna's directivity and boost data rates at both frequency ends. The antenna suggested in this work and the Vivaldi structure are positioned symmetrically to one another. Antennas are put together asymmetrically to reduce their size. The ground plane and the blade are connected by a feed line, which maintains the same voltage throughout the Vivaldi antenna system[10]-[12].

III. Proposed Methodology

The suggested antenna is based on a modified antipodal Vivaldi antenna, a class of slot antenna. Ultra-wideband antennas are necessary for contemporary wireless communication systems with high data rates and capacities, such as those utilized in microwave applications for tumor diagnosis, wall detection, and radar systems. Due to the high level of hardware integration and the device's size restrictions, the antennas must be small and low profile. To account for the quick attenuation of electromagnetic signals in human tissue, biomedical diagnostics require high-gain microwave imaging apparatus.

These systems' essential component is high-gain ultra-wideband antennas. A modified antipodal Vivaldi antenna can be made more compact without compromising radiation performance by applying the mirror image theory to it.High frequencies are used by antipodal, which has a strong focus. Rogers 5880, which has a dielectric constant of 2.2, a loss factor of 0.0009, and a thickness of 0.51 mm, is the substrate that was chosen for the antenna design. The substrate was used because it was simple to cut and manufacture, and it had characteristics like consistent electrical properties over a broad frequency range and resilience to chemical solvents and chemicals used in etching procedures.

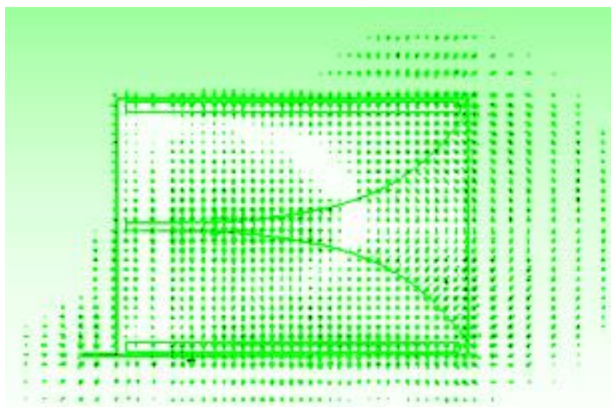

Figure 2. Vivaldi Antenna

Figure 2 depicts vivaldi antenna design.To figure out the substrate thickness, use a reference antenna that operates within the required frequency band and is suitable for the smaller antenna. Comparing the total dimensions of the reference antenna to the proposed antenna, which is 31mm x 19mm. 5.8 x 107 S/m is the conductivity of the copper metal utilized in the antenna. Use of the CST programme is made to carry out a recommended process for constructing an antenna. CST Studio Suite is a robust 3D electromagnetic analysis software tool for creating, evaluating, and optimizing EM systems and components. In order to ease stimulation, CST numerically calculates electromagnetic field problems in both the frequency and temporal domains using the Finite Integration in Technique. This programme is incredibly user-friendly and provides a great user experience.

For the design of the Vivaldi reference antenna, a FR-4 substrate with a thickness of 0.8 mm was employed. The suggested antenna's design parameters were optimized using CST Studio, a 3D electromagnetic solver, and the outcomes are displayed. The top and bottom layouts of the TSVA developed using all antenna design parameters are shown in Figure 2. An overview of the antenna excitation where W1 and W2 are the microstrip line widths that have been changed to create favorable matching circumstances.

3.1 A Tapered Slot Vivaldi Antenna with Polygonal Lens for multiband design technique

The gain in the higher frequency range was increased by using a lens and a director. Semi-elliptical lenses are ineffectual because the energy diffuses outside of the aperture, especially at high frequencies. As a result, for ideal focusing, the lens's shape is crucial. Therefore, polygonal dielectric lenses are advised. By extending the substrate with a polygonal frame that is as wide as the substrate, a lens is created.

Many proposed antenna designs are based on the idea of "mirror theory." According to the mirror image theory, the induced current in the electric wall brought on by the current in the radiating arm replaces the mirror image current in the radiating arm in its symmetrical position. In place of the second leaf arm, the antenna now has one leaf arm and one electric wall. The antenna's size is drastically decreased as a result. The lens's job is to focus energy onto the tapered slot Vivaldi antenna's aperture in the middle. To help with radiation enhancement in the endfire direction, a director is also printed on the lens side of the TSVA.Radially printed metal rectangles in three different length and width ranges make up the metal director. The mid-range gain is increased by using a director. Here is a picture of a Vivaldi-designed conical slot of antenna with lens and directorn as shown in figure 3.

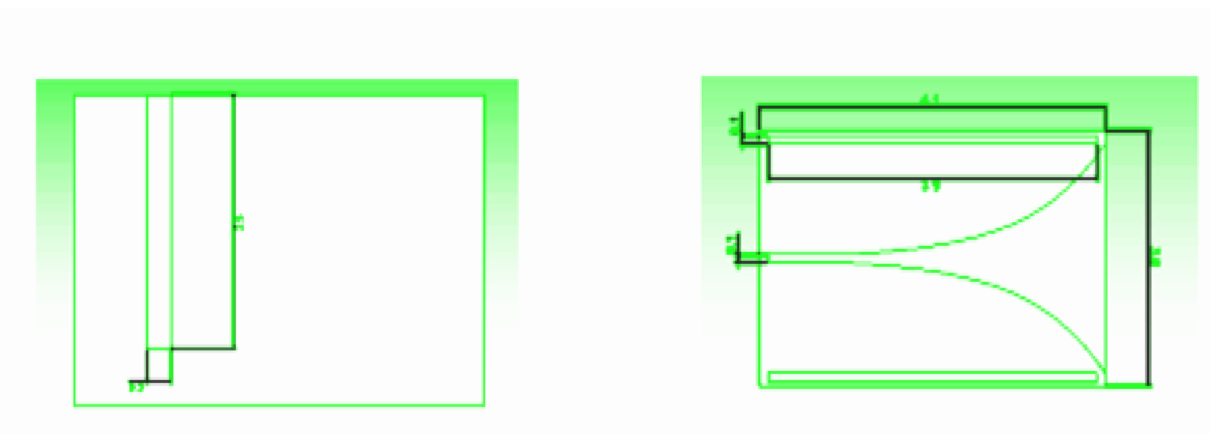

Figure 3. Slot Vivaldi Antenna for multiband design technique

The design of the proposed antenna (Fig 3)mainly depends on the concept of "Mirror image theory". According to the mirror image theory, the induced current on the electric wall due to current in the radiating arm replaces the mirror image current of the radiating arm at its symmetrical position. Hence resulting in a half mode structure of the antenna which has one leaf shaped arm and an electric wall that replaces another leaf shaped arm. This leads to considerable reduction in antenna size.

The lens's function is to focus energy onto the tapered slot Vivaldi antenna's aperture in the centre. In order to help with radiation enhancement in the endfire direction, a director is also printed on the lens side of the TSVA. The metal director is made up of metal rectangles with radial printing that come in three different lengths and widths. The mid-range gain is increased by using a director.

IV. Result and Discussion

The outcomes can be used to evaluate and assess the antenna performance for multiband design of passive planar microwave circuits. S-parameters, far-field, and efficiency simulations are performed using CST software. Designing, examining, and improving EM parts and systems requires the usage of CST Studio Suite, a 3D electromagnetic (EM) analysis application. With only one user interface, CST Studio Suite offers electromagnetic solutions for applications throughout the electromagnetic spectrum.

CST Studio Suite is utilized by many of the top engineering and technology firms in the world. Significant time-to-market benefits are provided through shorter development cycles and lower expenses. The use of virtual prototypes is a useful technique for simulation. Early layout-stage detection of compliance problems reduces the need for primary prototypes and lowers the likelihood of disastrous visual test outcomes and recalls. An electrical system's input-output interactions between ports are described using S-parameters. Instead of using voltages or currents to describe the network at high frequencies, waves should be used.

To find out how much power is reflected back to the same input with an antenna, measure the S11 parameter. It can presume that the antenna radiated these frequencies as EM waves if the reflection was minimal. S11 is a ratio scaled in decibels. An S11 value of less than -10dB is necessary to construct an antenna at a reasonable achievable frequency. A negative sign denoting reflected signal is used to indicate an input signal that is 10% reflected. At -3 dB, the input signal is 50%. The developed antenna is found to function best in his UWB range of microwave applications, which is the frequency range of 10-37 GHz, in accordance with the -15 dB norm. Figure 4 illustrates S parameter analysis of microwave circuit.

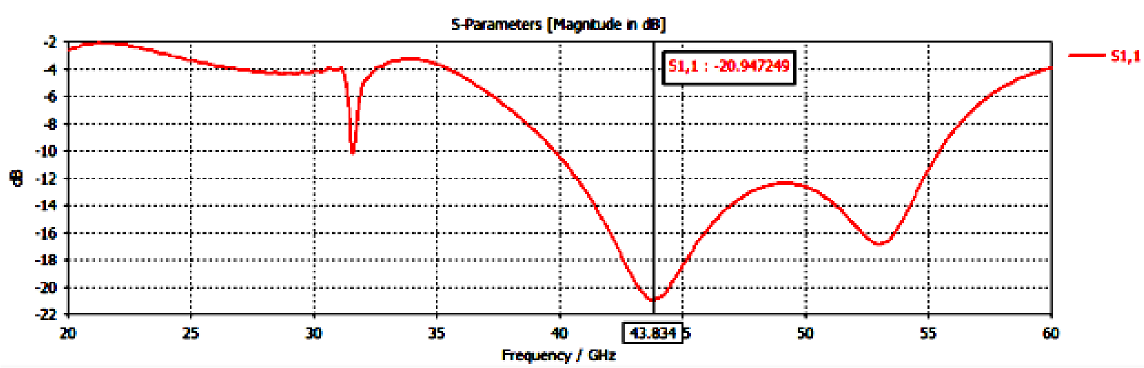

Figure4. S parameter Analysis for multiband design technique

An antenna's radiation pattern provides information about the antenna's capability to transmit and receive in various directions. The far-field produced radiation pattern for the three different frequencies of 40 Hz, 50 Hz, and 60 GHz is depicted in Figure 5. Due to its antipodal configuration, the radiating components of Vivaldi antennas exhibit good radiation characteristics. Radiation from antennas can be very specifically directed. Simulations indicate that the radiation efficiency is around -0.3844 dB. The strength of the stimulation antenna must be higher than 6.5 dB in order to cover the complete ultra-wideband spectrum of the relevant microwaves.Figure 5 indicates VSWR of multiband microwave circuit.

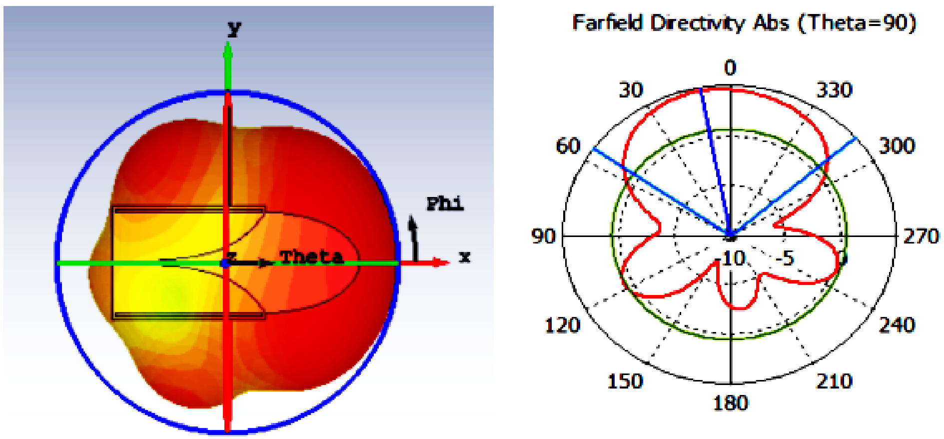

Figure 5. Far field polar directivity

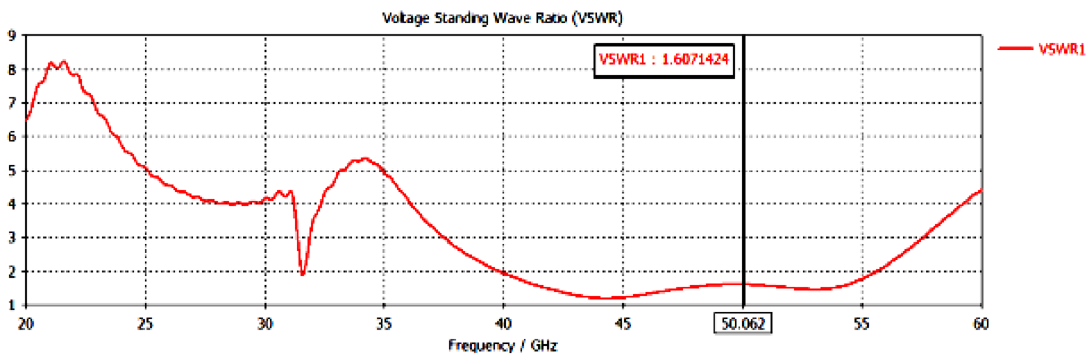

Figure 6. VSWR of multiband microwave circuit

V. Conclusion

A UWB Vivaldi antenna can be made smaller by using the HM design, which is based on the mirror image principle. As a result of the modification, the antenna used in multiband microwave circuit is 33% smaller than what was intended originally. This antenna covers the frequency range of 5.3 to 40 GHz and has a high data rate of 11 dB and a wide bandwidth. There is no Vivaldi antenna available in the HM design, but you can make a variety of slot antennas. An updated antenna design for multiband design methodologies covers a wide range of operating frequencies with VSWR less than 2.93%. Antenna size is reduced without affecting function, and far-field values are good throughout the frequency range.

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