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An Analysis of Wideband Phased Array Antenna System using with Micro strip Filter

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Abstract

Wideband phased array antenna system designed for multi-channel and multi-function process. Wideband phased array antennas consist of multiple fixed antenna elements, which can be energized in a different way and in order to manage the radiation pattern. The phased array antenna system is designed to work from 3 to 12 GHz. So each element is designed to work within the above bandwidth. Antenna elements are other important components of a phased array antenna. The dielectric substrate changes the effective dielectric constant of the micro strip line, and cause different phase shifts on the micro strip line.

Key Words: Wind band, Array, Antenna, Filter, TSA, Vivaldi, Transition, Vocal

I. Introduction

Linearly and exponentially tapered slot antennas were first introduced in 1979. Since tapering slot antennas (TSAs) are printed circuit antennas, their benefit of low down weight, the easiness of fabrication, and compatibility with microwave integrated circuits make them gorgeous in a lot of applications, such as satellite and wireless communications, remote sensing, and radar. As well as, TSAs can create a symmetric beam in both E- and H-plane by properly selecting the shape, length, dielectric thickness, and dielectric constant [1]. In addition, it is a traveling arrangement with structure, so that makes it appropriate for the transmission of the pulse signal rate without much dispersion in the time domain and TSA becomes a good applicant for ultra wideband systems that use thin pulse to transmit data. Common TSAs are of linear, exponential, or linear-constant width profile. Exponential TSAs are also referred as Vivaldi antennas system creating linear polarization shape.

TSAs can only create linear polarization. For applications that the polarization of the transmitting antenna is unidentified or for a moving target, circularly polarized receiving antennas are required. Spiral antenna is a good applicant for wideband circularly polarized applications. Traditional shapes of spiral antennas include the equiangular geometries and the logarithmically geometries. In theory base, spiral antennas have an infinite bandwidth, but it is the feeding structure deign and the truncation that bound the bandwidth rate. The minimum frequency of the operation, frequency occurs when the total arm length is equivalent to the wavelength. The maximum operation frequency is affected by the accuracy of the feed structure. In addition, the polarization is controlled by the arm length [2]. For minimum frequency, the arm length is small compared to the wavelength and the radiated field is linearly polarized shape. Because increases the frequency rate, the wave becomes elliptically polarized and finally accomplish the circular polarization. The phase shifter is one more significant part for a phased array. Newly, a PET-controlled multi-line phased shifter is reported. It features a number of advantages: low power utilization of less than 1 mW, high power handling ability, low dc control voltage of 60 V in comparison to that of a ferrite plate, smaller sizes, and no corresponding circuit required, and wider operation bandwidth due to a true time-delay type of phase shifting.

Band stop filters have create a lot of applications in microwave/millimeter-wave systems to reject unwanted frequencies. A shunt quarter-wavelength at the fundamental frequency open stub located at the output port of a doubler provides a low impedance level to reject the unwanted primary frequency and a high impedance level to allow the desired second vocal pass through. A diplexer using periodic stubs to reject the unwanted frequencies has a pass band between two adjoining stop bands. A dual-behavior resonator consists of two parallel open stubs of different lengths. Every one stub has its own stop bands, and then a pass b and is obtained among two adjoining stop bands. In addition, a band stop filter can be used as a RF choke to continue a transmission for direct recent and to choke off RF transmission over its stop bands [3]. In this research paper, micro strip band stop filters using with shunt open stubs and spur lines are presented. Basically, by cascading additional identical open-stub sections of an open-stub filter, a deeper rejection and a wider rejection bandwidth can be achieved at the expense of increasing circuit size and insertion loss. Spur line band stop filter with its essentially compact as individuality can be embedded between two adjoining shunt open stubs to introduce another lessening pole which achieves a better rejection presentation without any punishment of increasing size. As consequently, a band stop filter using the group of open stubs and spur line is proposed [4]. In addition, this band stop filter can be used to suppress the second vocal of an open-loop ring band pass filter or any other type of band pass filter. The planned band stop filter shows a 40 dB rejection upgrading at the second vocal.

II. Wideband linearly polarized phased array antenna system

Wideband phased array antennas consist of multiple fixed antenna elements, which can be energized in a different way and in order to manage the radiation pattern [5]. In a fundamental phased array the elements are fed logically and at all elements phase shifters or time-delays are used to examine the beam on the way to preferred directions in the space. Phased array antenna systems can be used in numerous applications.

A. Micro strip line to slot line transition process

The phased array antenna system is designed to work from 3 to 12 GHz. So each element is designed to work within the above bandwidth. The Figure: 1 (A&B) shows the configuration design and equivalent circuit of a micro strip line to slot line transition.

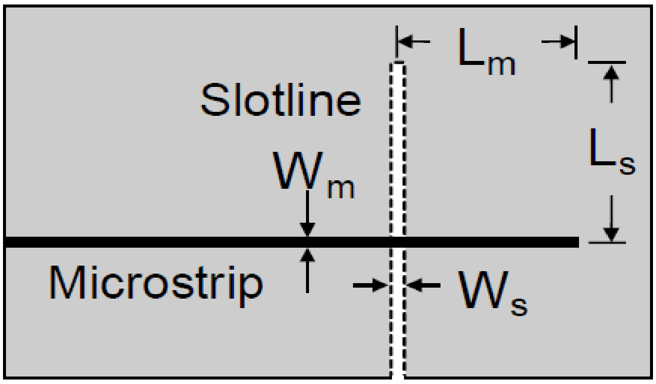

Figure 1 (A): Micro strip line to slot line transition process: Configuration Design

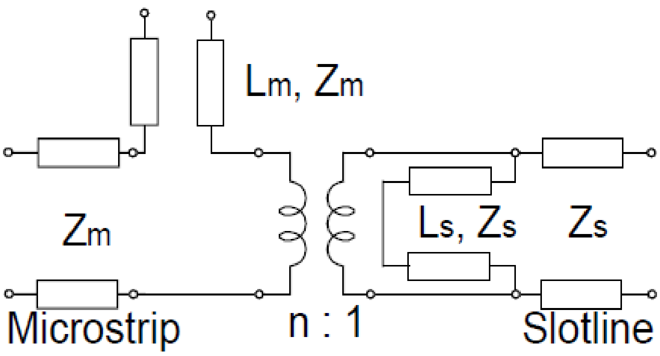

Figure 1 (B): Micro strip line to slot line transition process: Equivalent Circuit.

The micro strip line and slot line both are different sides of the substrate. At a given frequency, an impedance matching can be obtained by selection of line.

$$Z_m = n^2 Z_s \quad \text{.....................(I)}$$

Where:

$$n = \cos\left(2\pi\frac{h}{\lambda_0}u\right) - \cot q_0 \sin\left(2\pi\frac{h}{\lambda_0}u\right)$$

$$q_0 = 2\pi\frac{h}{\lambda_0}u + \tan^{-1}\left(\frac{u}{v}\right)$$

$$u = \sqrt{\varepsilon_r - \left(\frac{\lambda_0}{\lambda_s}\right)^2}$$

$$v = \sqrt{\left(\frac{\lambda_0}{\lambda_s}\right)^2 - 1}$$

Where h is the substrate thickness, ε_r is the related to dielectric constant of the substrate, λ_0 is the free space wavelength at the specified frequency, λs is the supervise wavelength of the slot line at the specified frequency, Z_m and Z_s are the impedances feature of the micro strip line and slot line, in that order [6]. Because the slot line impedance feature increases assist width *Ws* increases, the slot line width should be as small as possible for low impedance feature and the ease of impedance matching.

B. Vivaldi antenna system

With the wideband transition process, the full-wave electromagnetic simulator software CST Microwave Studio is used to decide the optimal taper factor *R*, the length *L*, and the opening width *W* [7]. The dimensions of the Vivaldi antenna shown in Figure 2, in this *L* = 150 mm (1, λ_0), *W* = 100 mm (0.67 λ_0), *D* = 0 mm and *R* = - 0.15, where λ_0 is free space wavelength at 2 GHz. The exponential taper is selected for its wideband performance. The slot flare is decided by a taper factor *R* according to the following equation.

$$y = c_1 e^{Rx} + c_2 \quad \text{.... (II)}$$

Where $c_1 = \dfrac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}}$, $c_2 = \dfrac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}}$.

The start and end points of the flare up decide the constants c_1 and c_2. In this case, the coordinate of start point (x_1 , y_1) is (0.1 , 0), and that of the end point (x_2 , y_2) is (50 , 150) with the origin at the center of the slot line with W_s = 0.2.

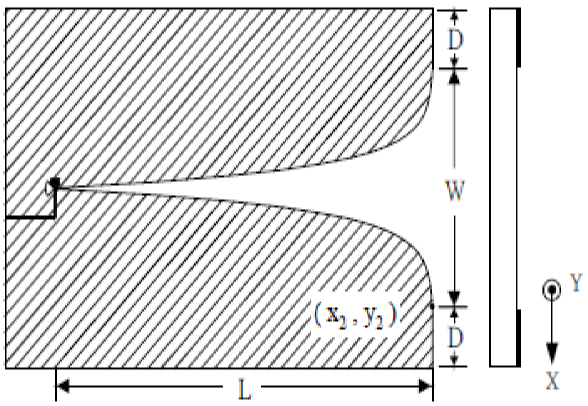

Figure 2: Vivaldi antenna system

III. Band stop filter using open stubs and spur line

In this Figure 3, that shows the configurations design of the band stop filters using with two shunt open stubs, a spur line, and the combination of two open stubs and a spur line. As shown in Figure 3 (a), the two stubs are λg/4 apart, and the stub length is λg/4, where λg is the guided wavelength of the micro strip line at the center frequency [8]. The spur line filter is build of a λg/4 L-shape thin slot embedded in micro strip line. Essentially, in order to obtain a deeper rejection and a wider stop band of the open-stub filter, more open stubs be supposed to working. However, it would also enlarge the circuit size and the insertion loss [9]. The further, spur line filter is appropriate only for reasonable rejection bandwidth about 10% applications. To overcome in this problem, a band stop filter using a spur line sandwiched among two open stubs is planned as shown in Figure 3 (c). Compared with Figure 3(a), the additional spur line shown in Figure 3 (c) introduces one more attenuation pole to found a deeper rejection and a wider stop band without increasing the circuit size [10]. In addition, compared with Figure 3(b), the planned filter provide a wider rejection bandwidth, since as introducing the two open stubs that are appropriate for wideband applications.

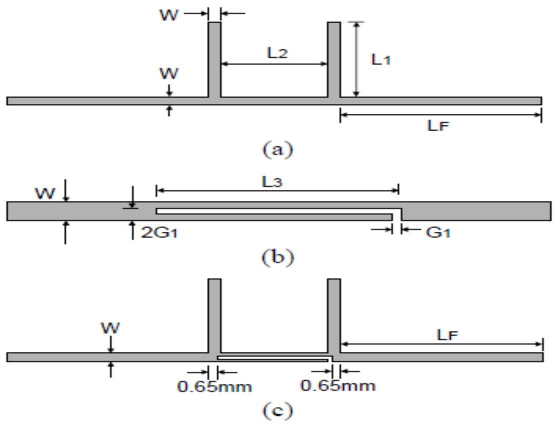

Figure 3: Configurations of band stop filters using (a) open stubs (b) spur line and (c) combination of open stubs and spur line.

Everyone filters are built on 25-mil RT/Duroid 6006 as dielectric constant = 6.15 substrates, and the simulation is performed by a profitable full-wave electromagnetic simulator IE3D*. Both of the two conventional filters are planned with the center frequency of 4.5 GHz. The optimized dimensions for parameters are: *L1* = 7.9 mm, *L2* = 8 mm, *L3* = 8.5 mm, *G1* = 0.3 mm and *W* = 0.9 mm for a 50 ohm line. *LF* is select as 15 mm for the convenience of measurements. Figure 4 shows the simulated and measured results [11]. The measured 20-dB rejection band of the open-stub, the spur line, and the planned filters are 3.9-5 GHz, 4.3-4.5 GHz, and 3.7-5.4 GHz, respectively, and the planned filter have the deepest rejection level of 61 dB between these three filters. In the condition of the same circuit sizes, the planned filter shows a better rejection than the traditional open-stub filter [12]. In addition, the planned filter has a wider stop band than the spur line filter.

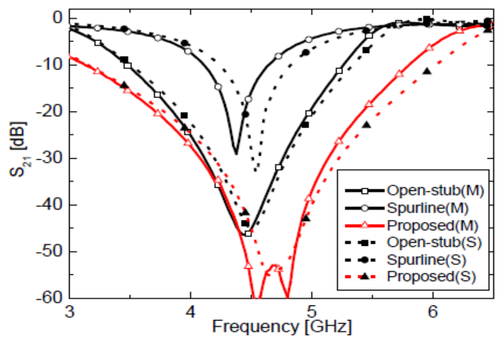

Figure 4: Simulated and measured insertion loss of band stop filters. M represents measurements, and S represents simulation.

IV. Band pass filter with second vocal suppression

The figure 5 shows the configurations design of an asymmetric-fed open loop ring band pass filter with and without the band stop filters so as to use to suppress the second vocal of the band pass filter [13]. The dimensions of these filters are: L_1 = 8.7 mm, L_2 = 8.4 mm, L_3 = 8.5 mm, L_4 = 13.95 mm, L_5 = 19.75 mm, L_6 = 11.6 mm, G_1 = 0.3 mm, G_2 = 0.5 mm, G_3 = 0.4 mm and W = 0.9 mm.

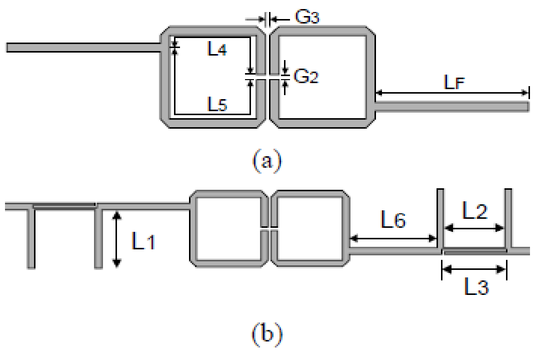

Figure 5: Configurations design of filters using two open-loop ring resonators (a) filter only and (b) Filter with proposed band stop filters.

The Figure 6 shows the measured insertion loss of the band pass filter only and band pass filters with the proposed band stop and the open-stub filters.

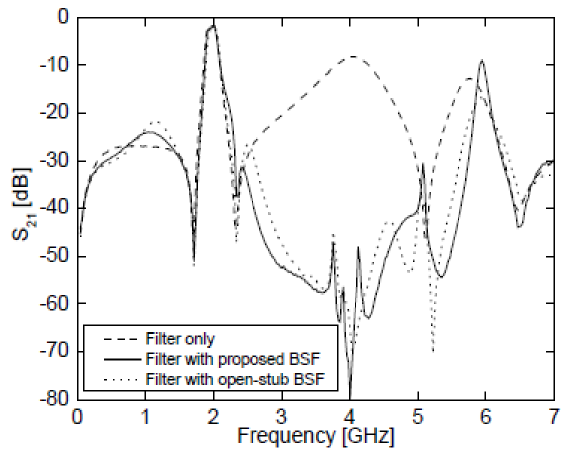

Figure 6: Measured insertion loss of band pass filter with without band stop filters.

The center frequency of the band pass filter is 1.95 GHz, and the second vocal at 3.9 GHz is suppressed from 8 dB without band stop filter to 48 dB with the band stop filter. The development in suppression of 40 dB is achieved. In addition, the proposed band stop filter shows an improved suppression performance than the conventional open-stub filter [14]. Figure 7, shows the measured and the simulated results of the ring band pass filter with the band stop filters. The simulated return loss is better than 20 dB. The measured pass band ranges from 1.9 to 2 GHz. The return loss is better than 10 dB, and the insertion loss as well as connector loss is less than 2.4 dB. The difference between simulation results and measured results is mostly due to fabrication tolerance[15]. From 2.3 to 5.7 GHz, the repression is better than 30 dB, and when less than 1.8 GHz, the suppression is better than 24 dB.

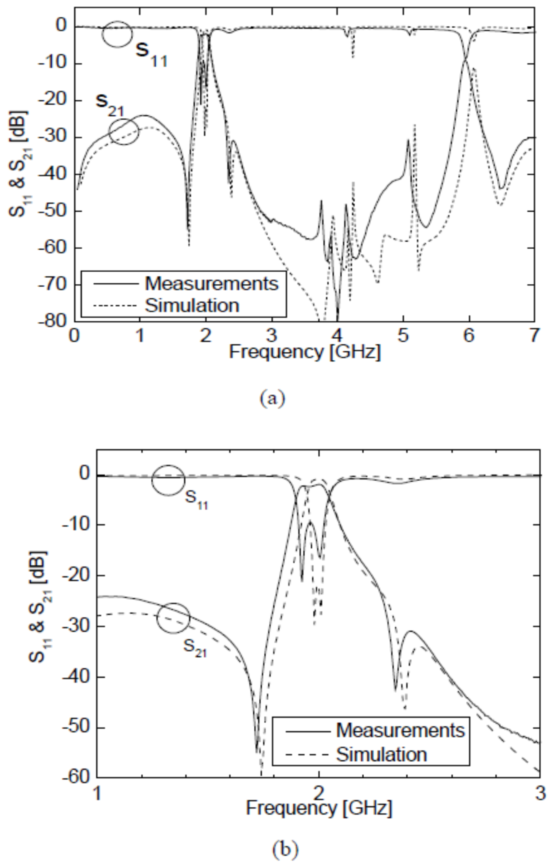

Figure 7: Simulated and measured results of band pass filter with band stop filters (a) whole frequency range and (b) near pass band frequency.

V. Conclusions

By applying the naturally impenetrable feature of spur line, a band stop filter using with the combination of open stubs and a spur line is planned. The planned band stop filter shows a large amount of deeper rejection and wider stop band than the conventional open-stub band stop filter without increasing the circuit size. This filter is also used to suppress the second vocal of an open-loop ring band pass filter with a center frequency of 1.95 GHz. The repression is better than 30 dB, from 2.3 to 5.7 GHz.

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