Improvement of antenna decoupling in radar systems

By: Anchidin, L (Anchidin, Liliana)[1]; Topor, R (Topor, Raluca)[1]; Tamas, RD (Tamas, Razvan D.)[2]; Dumitrascu, A (Dumitrascu, Ana)[2]; Danisor, A (Danisor, Alin)[2]; Berescu, S (Berescu, Serban)[2]

ADVANCED TOPICS IN OPTOELECTRONICS, MICROELECTRONICS, AND NANOTECHNOLOGIES VII
Edited by: Cristea, I; Vladescu, M; Tamas, R
Book Series: Proceedings of SPIE
Volume: 9258
Article Number: 925831
DOI: 10.1117/12.2070179
Published: 2015
Document Type: Proceedings Paper

Conference

Conference: 7th International Conference on Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies (ATOM-N)

Location: Constanta, ROMANIA

Date: AUG 21-24, 2014

Sponsor(s): Politehnica Univ Bucharest, Optoelectron Res Ctr; Constanta Maritime Univ; Romanian Minist Educ; Teamnet Int; Advi Tech Consulting RL; SOEL Syst SRL; Electromagnetica S A; WING Comp Grp SRL; Agilrom Sci

Abstract

In this paper we present a type of antipodal Vivaldi antenna design, which can be used for pulse radiation in UWB communication. The Vivaldi antenna is a

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Liliana Anchidin[*1)], RalucaTopor[1)] ,Razvan D. Tamas[2)], Ana Dumitrascu[2)]
Alin Danisor[2)], Serban Berescu[2)]

[1)] Department of Telecommunication, University Politehnica of Bucharest, Romania
[2)] Department of Electronics and Telecommunication, Constanta Maritime University, Romania
Bd. Iuliu Maniu 1-3, Sector 6, 061071, Bucharest

ABSTRACT

In this paper we present a type of antipodal Vivaldi antenna design, which can be used for pulse radiation in UWB communication. The Vivaldi antenna is a special tapered slot antenna with planar structure which is easily to be integrated with transmitting elements and receiving elements to form a compact structure. When the permittivity is very large, the wavelength of slot mode is so short that the electromagnetic fields concentrate in the slot to form an effective and balanced transmission line.
Due to its simple structure and small size the Vivaldi antennas are one of the most popular designs used in UWB applications. However, for a two-antenna radar system, there is a high mutual coupling between two such antennas due to open configuration.
In this paper, we propose a new method for reducing this effect. The method was validated by simulating a system of two Vivaldi antennas in front of a standard target.

Keywords: Vivaldi antenna, radar systems, mutual coupling, parasitic resonator.

1. INTRODUCTION

Target detection relies on the principle of radio wave reflection from metal and dielectric objects. This method can also be used to find the distance to the remote object from the transmitting station, by measuring the elapsed time between the transmitted radio signal and the corresponding echo received after the reflection of the signal on the object1.
The mutual coupling between antennas has a crucial importance for radar systems, since part of the signal would not be reflected by the target but directly transferred by mutual coupling. This effect can actually be reduced by placing a small parasitic resonator in-between antennas. This resonator has two long arms with opposite current flow, which causes their contributions to the far field to be canceled by each other, preventing destructive effects on the radiation properties of the elements.
This technique has been successfully applied to patch antennas2. In our work we propose to extend this technique to Vivaldi antennas3 and we show that decoupling can be significantly increased. In order to demonstrate the effectiveness of this method we simulated an antenna system for a radar4, illuminating a target.
Firstly, we considered as a target an infinite plane reflector and we show that the signal received by reflection can be exploitable. Next we performed the same simulation but on a finite size target.

2. ANTENNA SYSTEM WITHOUT RESONATOR

Firstly, we consider as a target an infinite plane reflector and we compare the signal received by reflection to that issued from mutual coupling. The system under assessment is shown in figure 1.

Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies VII,
edited by Ionica Cristea, Marian Vladescu, Razvan Tamas, Proc. of SPIE Vol. 9258,
925831 · © 2015 SPIE · CCC code: 0277-786X/15/$18 · doi: 10.1117/12.2070179

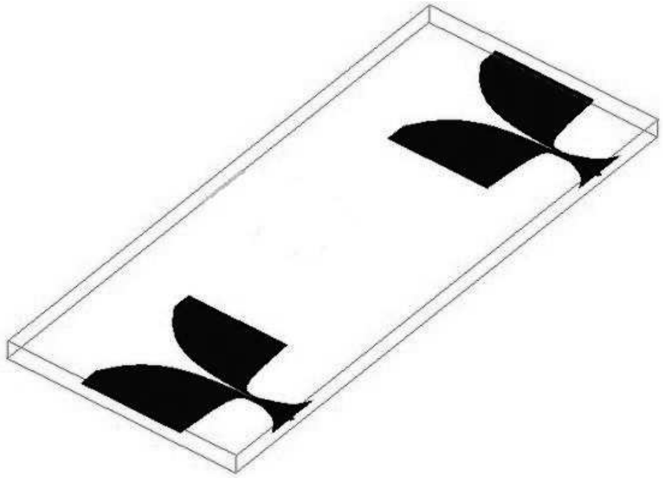

Figure 1. Layout of the antenna system

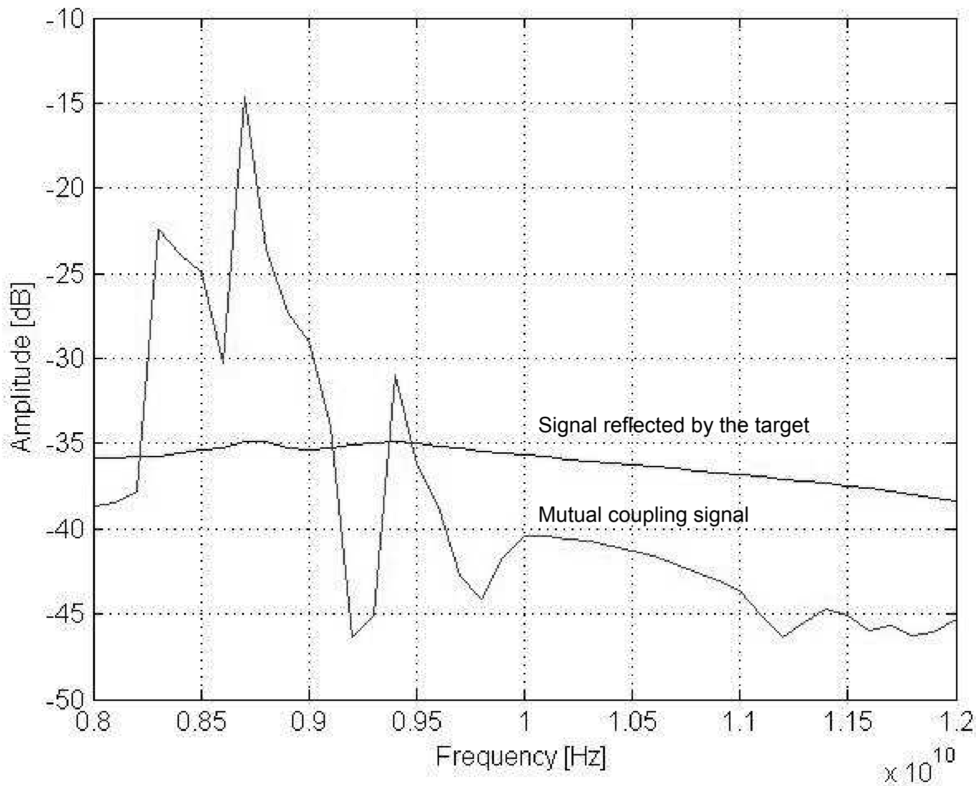

Figure 2. Simulation results without resonator

When two patches are placed one next to another, mutual coupling occurs both through the substrate and through the air layers on each side of it. The coupling through the substrate is due to surface waves. The coupling through the air layers is a direct near-field coupling. Either of the two couplings may become dominant depending on the precise topology and its dimensions[2].

3. ANTENNA SYSTEM WITH RESONATOR

Figure 3 shows the signal received by reflection on an infinite size reflector (green curve) and the signal that would be transferred between antennas by mutual coupling (red curve). It can be noted that the mutual coupling does not affect the target detection all over the frequency range.
As shown in the previous section, the signal level received by reflection on the target is lower than that resulting from mutual coupling. That actually can affect the detection threshold of the radar system.
We therefore optimized the system by inserting a conductive resonator between the antennas, as shown in figure 4.
The size of the parasitic resonator is 32.7 mm in length, 14.4 mm in width, and 3 mm in thickness.

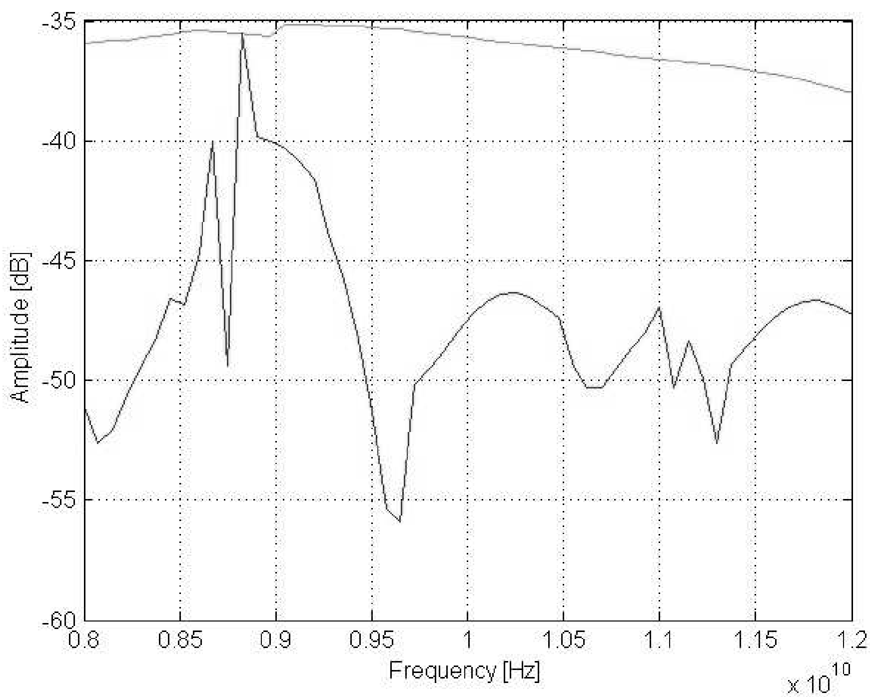

Figure 3. Simulation results of the antenna system with resonator on an infinite reflector

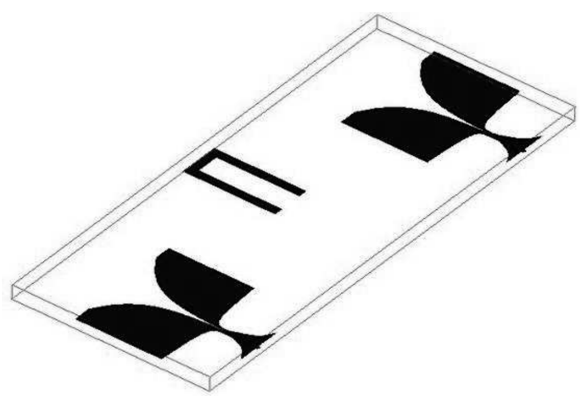

Figure 4. Layout of the antenna system with conductive resonator between the antennas

A similar simulation has been performed on a finitie size rectangular target to 100 mm by 200 mm. The results show that the mutual coupling[5] does not affect the target detection if the radar system operates around 9.65 GHz.
This improvement is actually due to our decoupling technique. The results are shown in figure 5, and it can be noted that there is a less difference between the two signals.

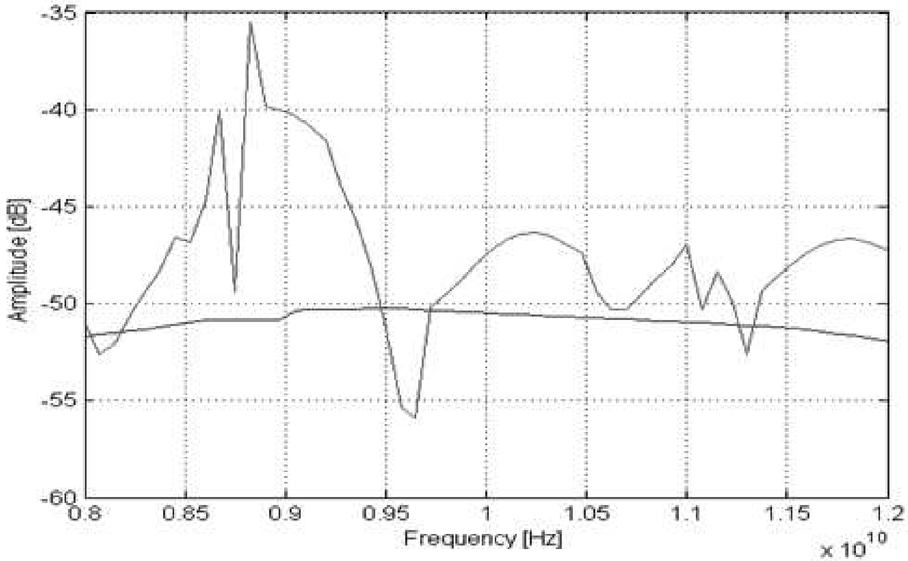

Figure 5. Simulation results of the antenna system with resonator on a finite reflector

For the antenna system without resonator, at a frequency of 9.65 GHz, the mutual coupling is lower than -45 dB, as shown in the figure 2. By using a resonator, the mutual coupling is reduced by at least 10 dB at the operating frequency. It can be seen that the improvement was achieved over a wide bandwidth, as required for a typical radar application.

Figure 6 shows the E-plane radiation pattern at 9.65 GHz. It can be noted that the main lobe is quite wide, as there is a small gain variation between 58 and 122 degrees. The presence of the resonator does not essentially affect the radiation properties of the antenna system.

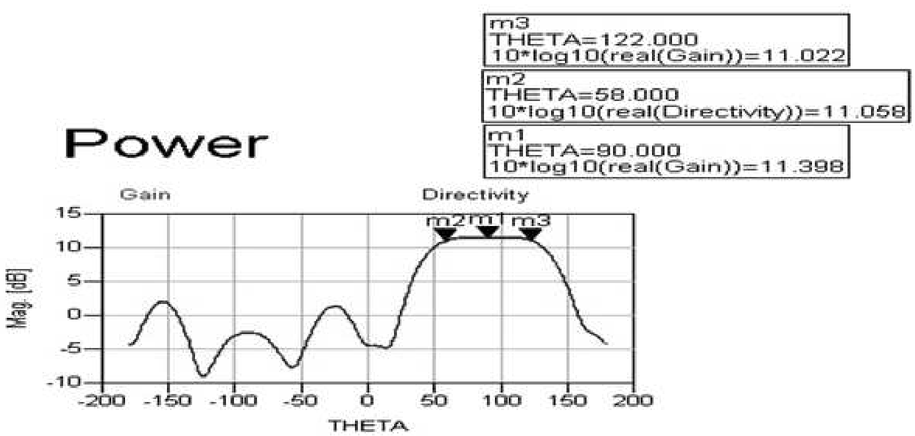

Figure 6. E-plane radiation pattern

4. EXPERIMENTAL RESULTS

In order to validate the application of the proposed technique to Vivaldi antenna systems, we manufactured two identical antennas and the corresponding resonator. The antenna system was scaled down to 2.4 GHz, since we did not have access to a vector network analyzer operating at higher frequencies.
The experimental results are shown in figure 7 and 8, for the configuration without resonator and with parasitic resonator, respectively.

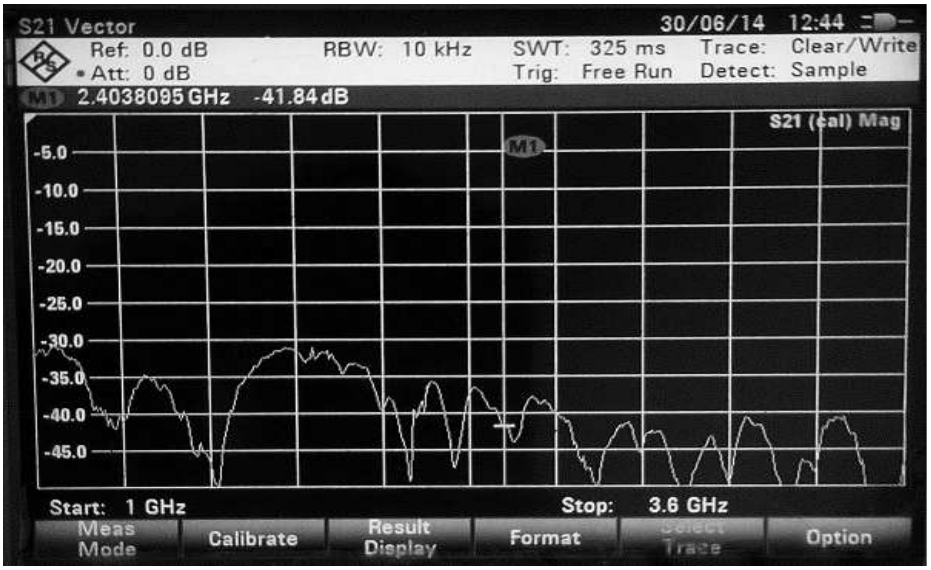

Figure 7. Measurement results without resonator

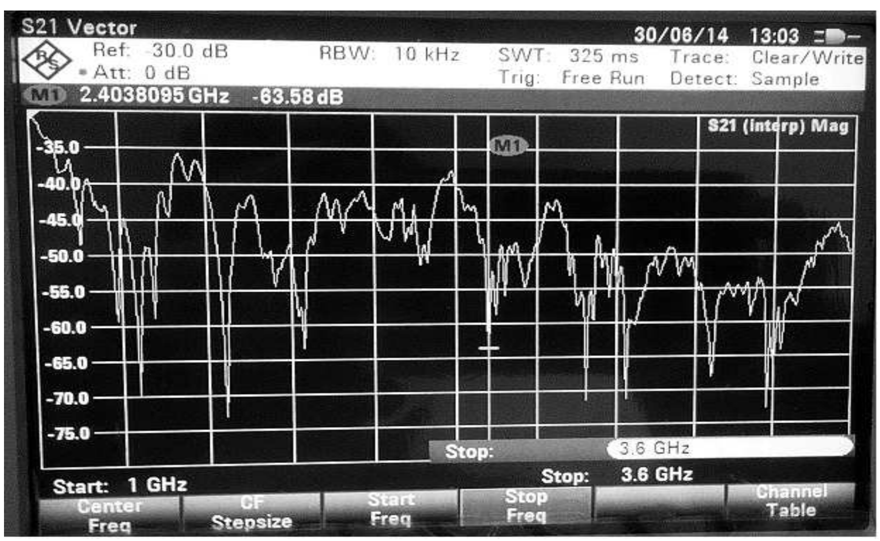

Figure 8. Measurement results with resonator

5. CONCLUSIONS

This paper proposes a decoupling technique for a 2-element, coplanar Vivaldi antenna system. We showed by simulation and measurements that the use of a parasitic resonator in-between the antennas can improve the mutual coupling by at least 10 dB.

The effectiveness of the proposed technique was validated by simulating the behavior of the antenna system in the presence of two hypothetical targets, i.e., an infinite reflector and a rectangular plate, respectively. It comes out that the improved antenna system can handle signals coming from finite targets, for short range radar applications.

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