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35 GHz Vivaldi Fed Antenna Design for Passive Millimeter Wave Imaging System in Ka Band

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Abstract: This antenna will be used for PMWIS (passive millimeter wave imaging system) which has 35 GHz operating frequency described as Ka Band. The antenna should work in that specific frequency because of having low attenuation in that region according to frequency behavior in misty conditions. Antenna also should have approximately 50 ohm input impedance value so that perfect matching to the active circuits will occur. The input reflection coefficient, S_{11}, has to be under -20 dB and the gain of the antenna, has to be over 10 dB value for better efficiency. Microstrip Vivaldi Fed Antenna provides all of the conditions for imaging system, was designed by using Antenna Magus Computer Program and later it was designed in detail with Computer Simulation Technology Studio Suite Computer Program. The last format of the VFA has -23.1 dB input reflection coefficient, 48.55 ohm input impedance and 12.3 dB gain for 35 GHz OF. It is ready to connect to the LNA and detector, which are active circuits of the PMWIS. At the end, the detector will be connected to the VA and computer. The receiver of PMWIS is composed to the VFA connected to the other equipment that is defined above will scan elevation and azimuth angles, as a result; the VA will transfer the signals to the computer. Computer will show the user the scanning area image. In this system, antenna is the most important section and particular attention was given to the antenna in this study.

Key words: Ka band, passive millimeter wave imaging, Vivaldi fed antenna.

Nomenclature

PMWIS:	Passive Millimeter Wave Imaging System
CST:	Computer Simulation Technology
GHz:	Gigahertz
G:	Gain
S:	Scattering Parameter
VFA:	Vivaldi Fed Antenna
PCB:	Printed Circuit Board
dB:	Decibel
LNA:	Low Noise Amplifier
OF:	Operating Frequency
VSWR:	Voltage Standing Wave Ratio
RF:	Radio Frequency
SMA:	Subminiature Version A
PEC:	Perfect Electric Conductance
VA:	Video Amplifier
MATLAB:	Matrix Laboratory Program
CF:	Center Frequency

1. Introduction

Antennas are the most important parts of the electromagnetic circuits. The directivity, G, input reflection coefficient and coherence are figure of merits of the antennas. If the circuit is designed to the PCB, it will be the best choice to use microstrip antenna instead of horn antennas. Thanks to microstrip antenna, the converter from wave guide to PCB is not used, as a result; it will be less loss. In this work, VFA is designed to use with other circuits like LNA, detector and VA. The VFA has 12.3 dB G and -23.1 dB input reflection coefficient (S_{11}) at 35 GHz OF. The advantage of PMWIS is to provide viewing the image at foggy air conditions. The 35 GHz, 96 GHz and 220 GHz are some of the other important frequencies for PMWIS. The VFA's input impedance is 48.55 Ω, the closer to the 50 Ω, the better antenna design. In azimuth angle, the antenna scans from -59.9^{o} to 59.9^{o} and in elevation angle, the antenna scans from 14.9^{o} to 104.9^{o}. So that 899 × 1,199 pixel resolution image can occur on computer screen. The antenna will send the signals to the LNA and LNA transfers them to the VA. Therefore, the image will be on the computer screen in PMWIS

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application. The image on screen can be enhanced by other software. At the end, the view between scanning angles can be seen very well in foggy conditions. If the antenna works well, all of the system will work well too. In this paper, VFA for PMWIS is described in detail.

2. Performance Parameters

For most of the antennas, the input reflection coefficient (S_{11}) should be under -20 dB and the input impedance should be close to the 50 Ω RF impedance. Both of these conditions are achieved in this VFA. G and VSWR are the other parameters that particular attention should be given to for antenna design.

2.1 Input Reflection Coefficient

There are 3 frequency windows according to S_{11} graph of the antenna. The CFs of these windows are 30.528 GHz, 35.474 GHz and 40.845 GHz frequencies. For these frequencies, the input reflection coefficients have the minimum values. It can be said that, this design will work between 20 GHz and 42 GHz frequencies (Ka Band) because magnitudes are below -20 dB.

In this design, it is -23.1 dB for 35 GHz OF, see Fig. 1. All the simulations are done by two computer programs. In Fig. 2, the input reflection coefficient is obtained -20.3 dB for 35 GHz from Antenna Magus Computer Program. The frequency windows and CFs are very similar to the CST Studio Suite design.

2.2 Input Impedance

The LNA impedance is 50 Ω, the VFA will connect to the LNA circuit, therefore; the out part of the antenna should have 50 Ω impedance too. In this design, it has 48.5 Ω reference input impedance in Fig. 4. This value is acceptable for circuit analysis. Values for Fig. 3 are got from CST, mean real impedance is 47.28 Ω and mean imaginary impedance is -1.501 Ω for Magus.

2.3 Gain

Gain, G, or S_{21} is another specific performance parameter for antenna design. Most of the antennas should provide bigger than 10 dB G. The VFA's G for this design is greater than 10 dB after 24 GHz frequency and it is 12.3 dB for 35 GHz OF, see Fig. 5.

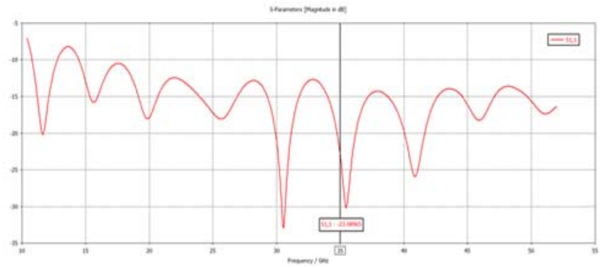


Fig. 1 S_{11} graph of the antenna from CST computer program.

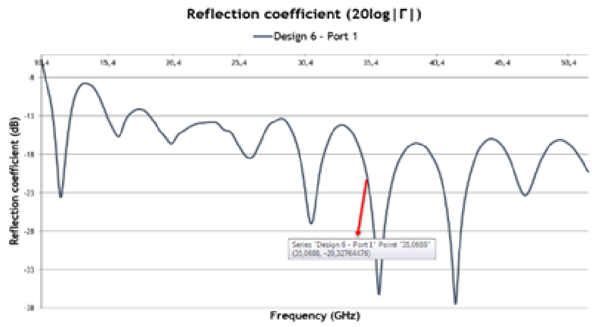
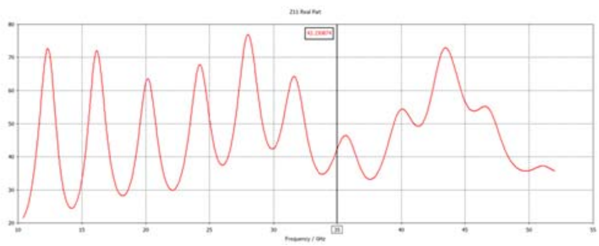
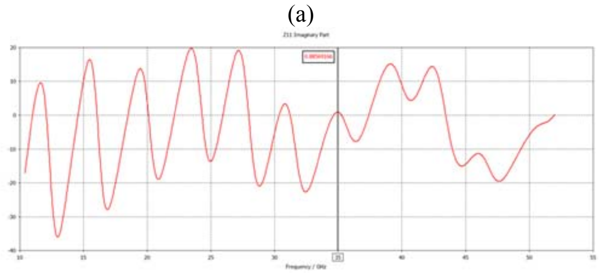


Fig. 2 S_{11} graph of the antenna from Magus computer program.



(a)



(b)

Fig. 3 (a) Real part of input impedance, (b) imaginer part of input impedance.

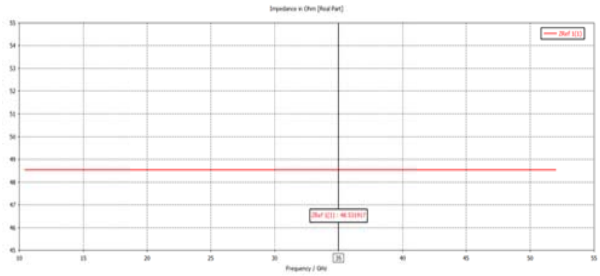


Fig. 4 Reference impedance.

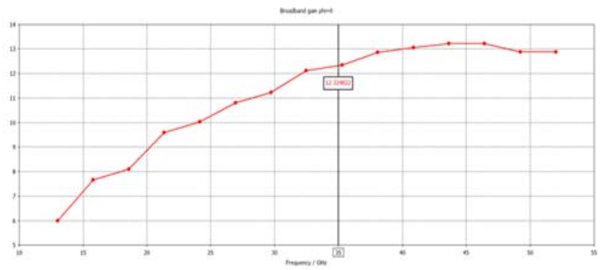


Fig. 5 Gain graph.

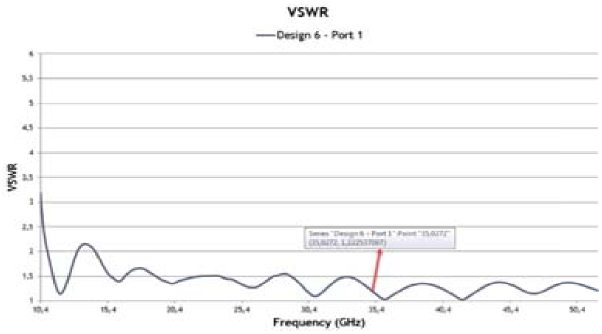


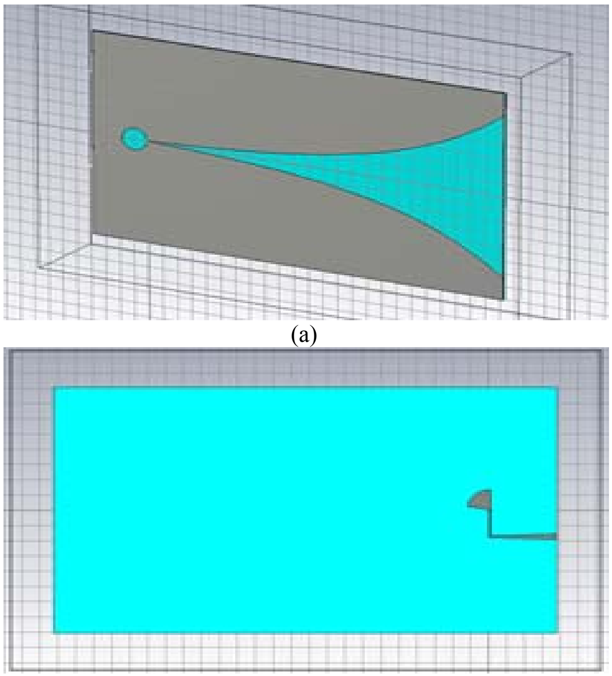
Fig. 6 VSWR graph.

2.4 VSWR

VSWR value should be close to 1 but not equal to 1. In this design the VSWR value is 1.22 that can be seen in Fig. 6.

3. Shape of Antenna

Vivaldi antennas are very similar to the horn antennas, the only difference is that horn antennas have three dimensions, vivaldi antennas have two dimensions. Thanks to vivaldi antenna, the connector from horn to PCB is not used. Vivaldi antennas can be connected to the PCB easily. Because the OF is high, 2.92 mm connector will be used for experiments. SMA connectors are for up to 26.5 GHz. The antenna will be connected with 2.92 mm connector to the LNA and the



(a)

(b)

Fig. 7 (a) Perspective view of antenna; (b) Fed part of antenna.

LNA will connect to the detector. The substrate's epsilon value is 3.27 and μ is 1 for simulations. Loss tangent value is 0. For the other parts of the antenna, PEC is used for simulations (Fig. 7a) and fed part of the antenna is also shown in Fig. 7b.

4. Results and Simulations

PMWIS applications work for some specific frequencies as 35 GHz, 96 GHz and 220 GHz. In this work, 35 GHz frequency was used and VFA was designed for this OF. The performance parameters: input reflection coefficient, input impedance, G and VSWR values, were intensively studied. Lastly, shape of antenna was given in detail.

If the antenna connects to the other circuits like LNA, detector and VA, the image which is between azimuth and elevation scanning angles appears on the computer screen. After enhancements in the computer program such as MATLAB, the image will get well. In the end, the image will be seen in foggy air conditions.

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