A Ka-Band Horn Antenna Excited with Parasitic Dielectric Resonator Antenna

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***Abstract*— A pyramidal horn antenna excited with parasitic dielectric resonator (DR) antenna for use at Ka-band frequencies is proposed. This antenna been divided into two parts, microstrip-fed rectangular slot DR antenna and a pyramidal horn. DR antenna consists of five identical cylindrical parasitic DR fed by a microstrip feedline through a coupling rectangular slot in the ground plane between them. It is designed to parasitic type for high gain, high isolation and wideband characteristics. Simulated result shows the antenna produce high gain that is larger than 19.8dB. CST simulation results of the electrical performance for pyramidal horn antenna operating at 38GHz are presented.**

Keywords-Horn Antenna; Ka-Band; Dielectric Resonator Antenna

I. INTRODUCTION

A high data rate communication systems requires efficient antennas in particular, pyramidal horn antennas are used. This antenna is suitable for high gain, high power, and broadband applications. Advantages of this type of antennas are low level of lateral and back radiations, possibility to function with very good directivity and gain properties. In general, antennas characteristic are conditioned by feeding facility, which is a weak point of the whole antenna. Also there is no general mathematical apparatus for such antennas analysis and synthesis. Therefore, designing a new feeding technique for Ka-band horn antenna excitation becomes the main task of this study.

In this paper, we propose a novel pyramidal horn antenna excited with parasitic DR antenna for use at Ka-band frequencies. This antenna comprises a microstrip-fed rectangular slot DR antenna and a pyramidal horn. DR antenna consists of five identical cylindrical parasitic dielectric resonators fed through rectangular slot-coupling. Cylindrical dielectric resonators of high dielectric constant have been used as they can offer some advantages at high frequencies over patch antennas in terms of ohmic loss and wider bandwidth [1, 2]. The slot-coupling mechanism was introduced by Pozar [3]. Furthermore, with slot coupling to the cylindrical resonator, the hybrid mode $HEM_{11\delta}$ is excited [4]. Under the above conditions the Q-factor is low (≈ 30) and this makes the structure a good candidate for an antenna element which combines the advantages of aperture coupling with the significant high frequency potential of DR antennas.

II. HORN FEEDING CONFIGURATION

Figure 1 shows the geometry of pyramidal horn antenna with feeding configurations. The antenna consists of a feeding rectangular waveguide section which is flared to reach a specified aperture size. The horn was designed to provide gain of 20dBi, using conventional design formula in [5]. Antenna is created on the base of extending rectangular waveguide, which the dimensions are chosen in order to make the field exists inside the horn be mainly TE_{01} mode at 38GHz. The inner sizes of the waveguides are 7.112 mm x 3.556 mm and the thickness of the walls is 0.2 mm. Maximum available gain for the horn antenna depends on the aperture size. The aperture of the horn is 35.34 mm x 27.43 mm and the length of the horn including the waveguides is 61.89 mm. The gain and the 3dB beamwidth are decided by adjusting the length of antenna.

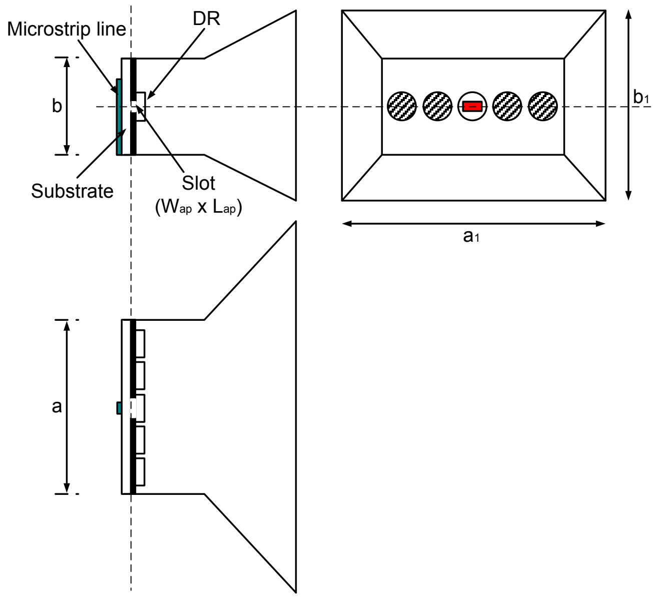

Figure 1. Physical horn antenna feeding configurations.

Five identical circular cylindrical parasitic DR is fed to the horn butt end as shown in Figure 2. The rectangular slot in the ground plane provides for the coupling from the 50-Ω feedline at the bottom to the center DR on the top while the four identical adjacent DR are electromagnetically coupled. By placing closely spaced parasitic resonators in the same plane of the driven DR, substantial enhancement of the bandwidth is obtained. Based on qualitative analysis, the $HEM_{11\delta}$ can be strongly excited by centering the slot at $\phi = 90^o$ along the y-axis [6]. The separation, between the driven and parasitic resonators is about 0.05mm. Slot lengths between 0.78 and 0.80 mm were used and the width was kept small to avoid a large backlobe component but it became a very narrow slot that may be difficult to fabricate due to etching limitations. A set of five resonators, for which, diameter, *D* and height, *h* of 1.1 mm (0.14 λ_o) and 0.4518 (0.57 λ_o) mm respectively was used, where λ_o is the free space wavelength at center frequency of 38GHz. It is fabricated from chemical composition of Ba Zn Ta Oxide dielectric material with relative permittivity ε_r=31 through conventional ceramic processing. The above dimensions were selected to provide resonant frequency at 38GHz. In view of the geometry and method of excitation, the main mode excited for this configuration will be the hybrid electromagnetic mode $HEM_{11\delta}$. To obtain an estimate of the resonant frequency, we assume an infinite, perfectly conducting, ground plane and use is made of the formula [4] :

$$f_{res} = \left\{ \frac{c_o}{2\pi} \sqrt{\varepsilon_r} \sqrt{\left(\frac{3.682}{d}\right)^2 + \left(\frac{\pi}{2h}\right)^2} \right\} \qquad (1)$$

The feedline substrate has a thickness of 0.25 mm and ε_r=3.0. The line extends beyond the slot about $\lambda/4$ to provide a tuning stub.

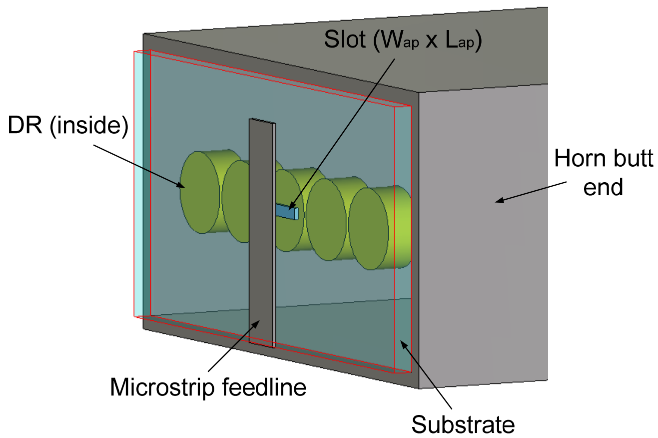

Figure 2. Five identical cylindrical dielectric resonator in the horn butt end.

III. EXCITATION ANALYSIS

The antenna as whole was analyzed and optimized using CST Microwave Studio ® software. CST software which is based on the finite integral technique is very useful for analysis of wideband antenna. Frequency domain response is obtained after a time domain response by using discrete Fourier transform. A 14.343 dB gain improvement is achieved by attaching the circular cylindrical parasitic DR to the pyramidal horn due to the radiation combination from both the slot and DR. Figure 3 shows the simulated return loss for the five cylindrical parasitic DR attached to the horn. Strong couplings were observed for the $HEM_{11\delta}$ mode with the parasitic resonators superimposed on driven DR at and near 38GHz. The bandwidth over which the return loss is less than 10dB is 2.16%, and this was obtained without any optimization of the design. Figure 4 shows the gain of the antenna at frequency range of 36 to 40GHz. Simulated result shows the antenna produce high gain that is larger than 19.8dB. It indicates that the antenna has high efficiency with minimum loss. This is because there is no conductor loss in the DR. However, conductor loss exists in the microstrip line but it is very small.

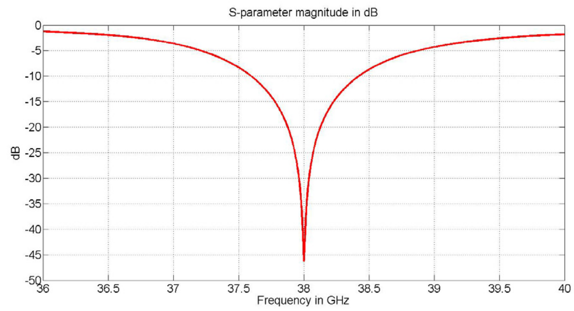

Figure 3. Simulated return loss against frequency of five cylindrical parasitic DR attached to horn.

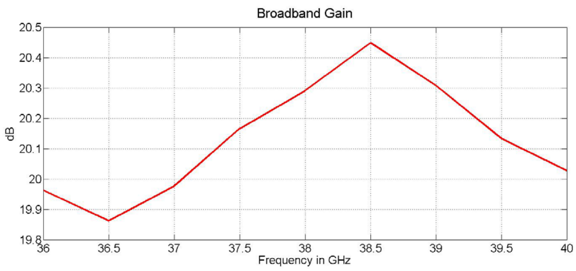

Figure 4. Gain of the antenna on dB-scale from 36 to 40GHz.

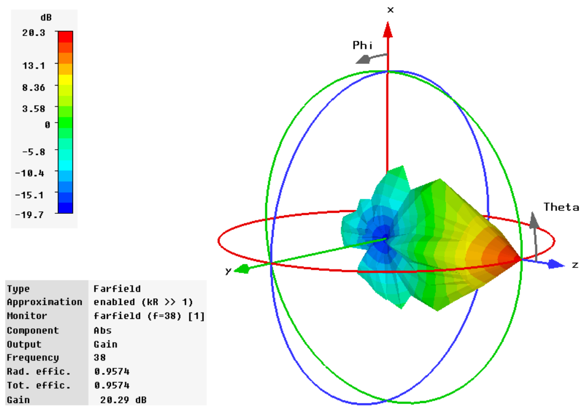

Figure 5. A 3-dimensional radiation pattern of the antenna.

A 3-dimensional pattern of the antenna is presented in Figure 5, showing a gain of about 20dB @ 38GHz, with excellent efficiency exceeds 90%. Figure 6 represent the simulated E-plane and H-plane radiation cut at 38GHz indicates the sidelobe level of 25dB with a gain of about 20dB. The flare angle of the horn is found to be responsible for the input match, as the length and the flare angle of the horn is due to radiation pattern.

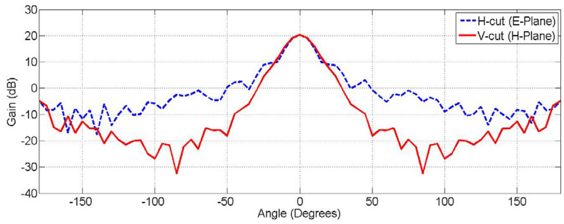

Figure 6. E-plane and H-plane radiation cut of the antenna.

IV. Conclusions

The design and performance of a practical horn antenna feeding configuration for use at Ka-band frequencies have been presented. A good simulation results for both return loss and radiation characteristics have been achieved. The gain of the antenna is considerably high. Bandwidth enhancement is achieved for the $HEM_{11\delta}$ mode with the parasitic resonators superimposed on driven DR. Wider bandwidth can be achieved by placing closely spaced parasitic resonators in the same plane of the driven DR. Excitation of DR in $HEM_{11\delta}$ shows an excellent return loss and radiation characteristics. By all of these properties, the proposed antenna can be applied for use at Ka-band frequencies. A prototype antenna is under fabrication work, to be followed by measurements.

Acknowledgment

Authors would like to thank Universiti Sains Malaysia for supporting the project.

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