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Reactive Loading of Dielectric Rectangular Waveguide Antenna for Better Impedance Matching

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Abstract:

A rectangular dielectric rod antenna fed by a metallic waveguide is investigated, with insertion of a metallic post at the pyramidal matching section between the dielectric slab and the metallic waveguide. Impedance matching between the dielectric rod and the metallic waveguide feed may be performed by inserting a tapered portion of the rod into the waveguide. As the length of the matching section increases, impedance mismatch is reduced at the cost of bulk and weight. Introduction of a conductive post within the matching section acting as a reactor improves the return loss to a huge extent without affecting the radiation characteristics. Computer simulated results along with corresponding measured values are presented.

Key Terms — return loss, impedance matching, radiation patterns

1. Introduction

A solid rectangular dielectric slab with one end open and fed by standard metallic rectangular waveguide operating in TE_{10} mode is one of the commonest dielectric antennas. Such antennas have been studied analytically [1]. Investigations on the radiation characteristics of a rectangular dielectric waveguide antenna using finite elements based computer simulation have been reported [2].

Impedance matching of the waveguide launcher to the radiator is to be ensured for their practical usage. The impedance and radiation characteristics of dielectric waveguide antennas with tapered matching sections inside the launcher, for their dependence on different physical parameters is provided [3]. The studies show that a good impedance matching can be achieved only by using an impracticably long taper, which would have made the antenna extremely bulky and added up to the fabrication cost. Further, a very long taper used for matching also changes the radiation patterns, which is often an undesirable phenomenon. To overcome these problems a conducting post has been placed in the matching section yielding encouraging results after optimization of its position and dimensions.

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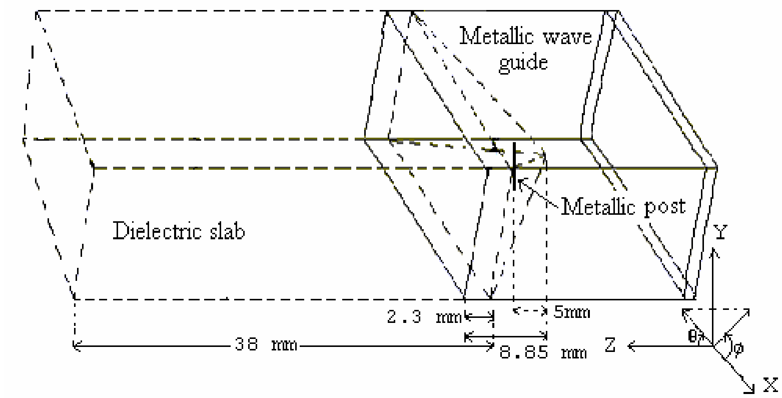

Fig. 1: Dielectric slab antenna with reactive loading

2. Methodology

Finite elements based electromagnetic simulation software (HFSS by Ansoft Corp., USA) has been used to investigate the dielectric slab antenna with tapered matching section. Then a metallic post is introduced within the matching section to act as a reactive load. Improvement in return loss is observed through simulation studies. Finally both position and dimensions of the post are optimized using computer simulation for best performance without any significant distortion of radiation patterns. The optimized configuration is tested experimentally for both impedance matching i.e. return loss and radiation patterns. Very good agreement between simulated and measured results is observed.

3. Results and Discussions

A rectangular dielectric waveguide antenna with pyramidal matching section using Teflon (dielectric constant 2.4) is designed to resonate at 10GHz and simulated for operation in the X-band. It is fed by a standard WR 90 X-band metallic waveguide.

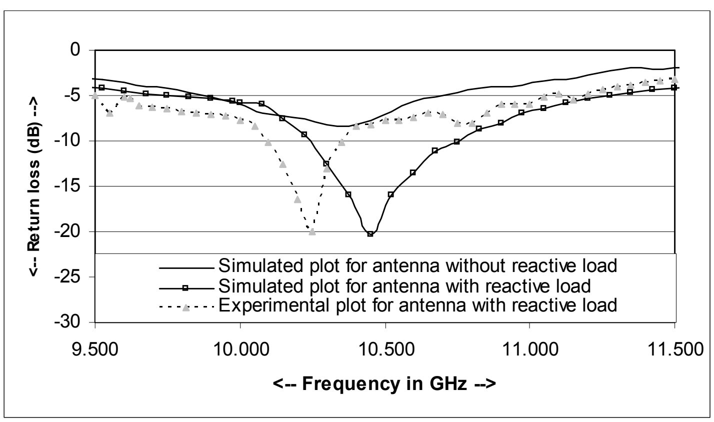

Fig. 2: Simulated and experimentally measured return loss plots for antenna without and with reactive loading

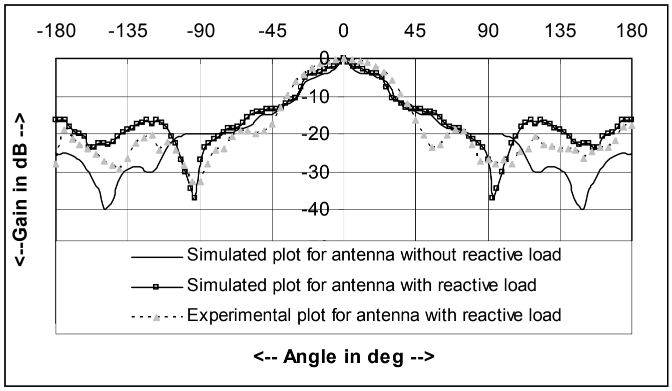

Fig. 3: Simulated and experimentally measured E-plane radiation patterns for antenna without and with reactive loading

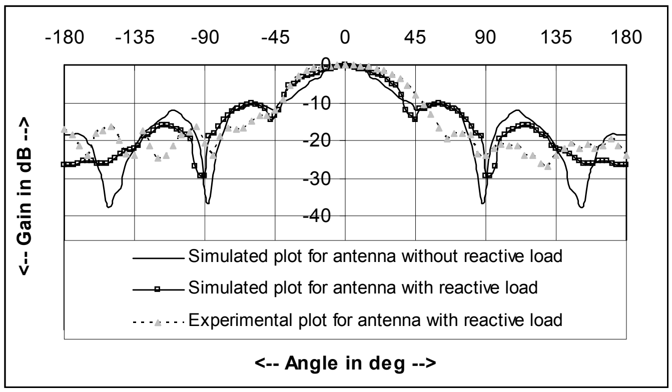

Fig. 4: Simulated and experimentally measured H-plane radiation patterns for antenna without and with reactive loading

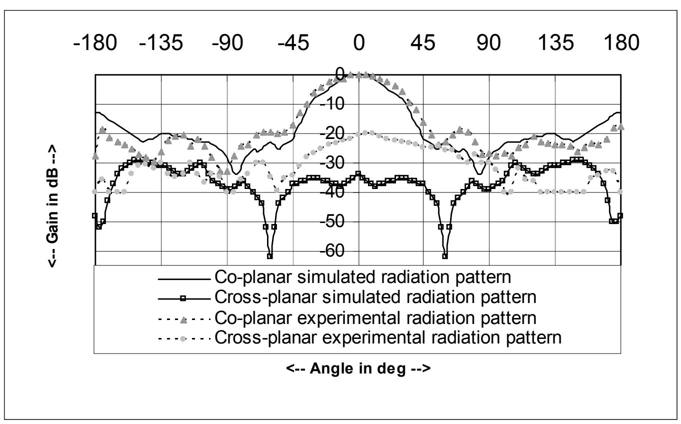

Fig. 5: Simulated and experimentally measured co and cross-planar radiation patterns for antenna with reactive loading

After introduction of a metallic post and optimizing its position as well as physical parameters, the antenna shown in fig.1 results. Fig. 2 depicts the return loss for the antenna with and without introduction of the post, whereby the antenna performance is found to improve drastically showing an improvement in return loss from –8.4 dB to –20.4 dB (V.S.W.R. 1.21). Measurements on the fabricated prototype using Vector Network Analyzer yields a minimum return loss of –20.1 dB with about 200 MHz shift in the resonant frequency, in close agreement with the simulated result. Measured radiation patterns for the same show front to back ratio of nearly18 dB with a 3 dB beam width of 30^0 in the E plane & 36^0 in the H plane. These patterns along with their simulated counterparts are shown in figs. 3 and 4. From these figures we find that there is practically negligible discrepancy between the simulated and measured patterns. Further, simulated patterns of the antenna without reactive loading are also presented in these figures, which proves that the radiation characteristics remain almost unaffected by the loading process. The on axis cross-polar discrimination level has been found to be approximately 32 dB (simulated), which is also very encouraging. However, measurements indicate a cross-polar discrimination level of approximately 20 dB, the difference being probably due to stray reflections in the measurement area and limited sensitivity of the measuring instruments.

4. Conclusion

It is observed that return loss behaviour can be dramatically improved by inserting a shorting post within the feed matching section of a rectangular dielectric waveguide antenna. The post acts as a reactive load and is able to scatter the wave propagating along the guide and control the propagation characteristics and field pattern from the aperture end. For even better performance, several posts can be used together forming an array. However, the bandwidth obtained with post loaded dielectric waveguide antenna is quite small (~1%) because of the high degree of frequency sensitivity of the load. Other forms of matching sections such as asymmetric taper and use of other tuning and loading structures are also being investigated.

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