Substrate Integrated Waveguide Antenna Feed - Design Methodology and Validation

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The substrate integrated waveguide (SIW) concept is proposed as a viable antenna feed operating at Ku-band. The efficiency obtained from integrating the feed technology with the antenna is comparable to the metallic waveguide feed, at a much reduced cost and increased miniaturization capability. Results are presented for a prototyped 2×4 subarray module, which exhibits a 16 dB gain.

Introduction

Antenna arrays based on microstrip technology have been traditionally been used in applications where their ease of manufacturing, low-cost, low-profile, and lightweight have been of primary importance. In many designs, a coplanar corporate feed network distributes the transmit/receive signal to individual elements of the array in order to keep a compact size of the overall structure. At higher microwave and millimeter-wave frequencies, this approach suffers from ohmic and dielectric losses of the connecting microstrip lines and undesired radiation of the feed network. Therefore, the realization of high-efficiency microstrip antenna arrays with a large number of elements can be a challenging problem, unless a low-loss, low-radiation feed replaces the coplanar one. Among all microwave transmission lines, hollow metallic waveguides feature extremely low losses up to very high frequencies and have been intensively utilized in the feed system of planar slot arrays and in the beam forming networks of satellite antennas. The authors have also proposed an ultra-low-loss waveguide feed network combined with a high gain microstrip antenna in order to enhance the overall radiation efficiency of the resulting hybrid array [1]. There are a number of drawbacks to a hybrid antenna system. First of all, the waveguide-fed antenna is bulkier due to the metallic feed network which limits the overall size of the structure. Secondly, the cost of integration is high because of the two conflicting technologies (metallic waveguide and PCB) used. An ideal structure should combine the ease of manufacturing and low-cost of microstrip elements with the performance of waveguides in one substrate. Here, the authors present a novel method for an antenna feed at Ku-band, which meets both goals of very low size, and very low loss such that it can be used successfully as a corporate feed network for antenna array systems.

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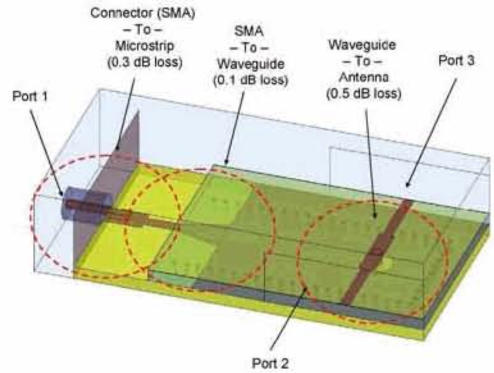


Figure 1: Complete SIW feed structure for antenna module.

Substrate Integrated Waveguide

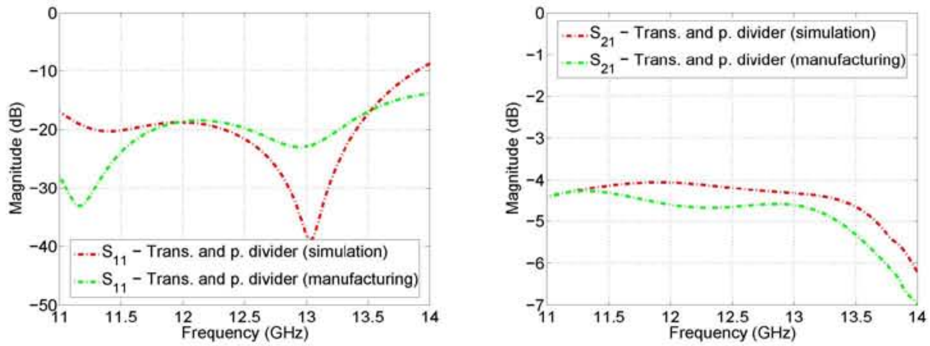
Substrate integrated waveguide (SIW) has been proposed as a viable antenna feed structure [2], [3]. SIW has all the advantages required for a small size antenna package: low-cost, high-performance, ease of integration, etc. SIW structures can be manufactured using standard PCB processes which further helps maintain a low cost of fabrication due to the single manufacturing and assembly step involved. Furthermore, a high accuracy can be maintained because of the precision of the varaious processing techniques. Companies used for the fabrication can routinely process all PTFE and non-PTFE based substrates, with thickness of $0.005 - 0.125$ *in.* and thickness plating of $0.5 - 3$ *oz.*, where 1 *oz* $\sim$ 30 *um* thickness.

SIW Array Feed Integration

The basic building blocks of the SIW technology have been designed, simulated, and fabricated, and their measurements results have been contrasted against computer simulations. In general the authors have seen good agreement between subcomponent simulations and measurements, which validates these structures for their proposed use in antenna feed applications.

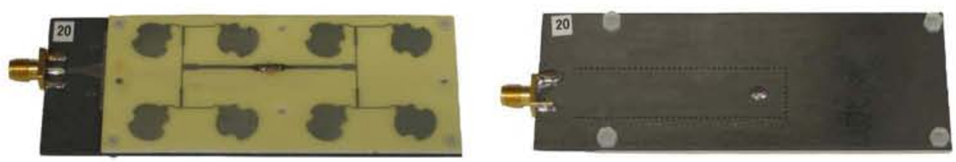
A complete antenna feed incorporates a key number of components relevant to the low-profile application. As such, the minimum number of components of a feed which can be scaled to a larger array include:

- input coupling (such as SMA) to connectorized components;
- microstrip circuit section which can possibly be used for integration of front end active circuitry;
- low loss microstrip to SIW tapered transition;
- SIW section - can be extended or cascaded with other SIW components such as T power dividers;
- SIW to microstrip (antenna layer) transition.



(a) (b)

Figure 2: Simulated and measured complete feed. (a) Return loss. (b) Insertion loss.



(a) (b)

Figure 3: Fabricated 2×4 array module with SIW longitudinal feed (a) Front view. (b) Back view.

The incorporation of various building blocks into a simple array antenna feed, starting from the input coaxial port to the top layer of microstrip antennas forms the complete feed. In Fig. 1 we illustrate the complete feed network. Based on HFSS simulations [4] we can estimate the loss for various sections of the antenna feed. In Fig. 1 the highest losses come from the SIW-to-microstrip transition ($\sim 0.5\ dB$) and the input SMA connector ($\sim 0.3\ dB$) which is modelled as a coax-to-microstrip transition. Further, the microstrip-to-SIW transition has a loss of $\sim 0.1\ dB$ which is attractive for future integration of front end planar circuitry (such as diode phase shifter and/or MIC LNA) with the feed network.

A comparison between simulation and measurement results is shown in Fig. 2 for the complete feed shown in Fig. 1, including input and output SMA connectors. The return loss is maintained to $|S_{11}| < -20\ dB$ values between the simulated and measured transitions, whereas the insertion loss is slightly higher in the measured structure.

2 × 4 High Efficiency Antenna

A number of antenna arrays with SIW feed were designed, fabricated, and measured and the results are presented here. The smallest module which is used as a building block for making larger arrays is a 2×4 circularly polarized array introduced earlier in [1]. The SIW integrated antenna is illustrated in Fig. 3.

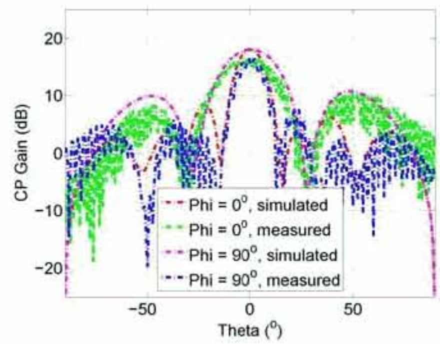


Figure 4: 2×4 module performance. Simulated and measured CP Gain, 12.5 GHz.

The simulation and measurement results of the antenna module agree very well as illustrated in Fig. 4. A gain of $\approx 16dB$ results in an aperture efficiency of $> 60\%$ which is better than or equal to equivalent metallic feeds at a fraction of the cost. Scalability of the antenna to larger structures will be investigated by the authors in a future work.

Conclusion

The authors presented a new waveguiding structure which shows very good performance at Ku-band frequencies. A prototyped antenna profiting from this feed illustrated very good agreement between simulation and measurement results.

Acknowledgements

The authors want to thank MASSolutions Inc., the Ontario Centers of Excellence (OCE), and the Natural Sciences and Engineering Research Council (NSERC) of Canada for their support.

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