A W-Band Corrugated Output Horn and Window for Gyro-devices

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Abstract—**A W-band corrugated horn incorporating a broadband vacuum window for use in a gyro-device as a quasi-optical launcher has been designed, manufactured and experimentally measured. This horn, including a 3 disk vacuum window, converts a cylindrical TE_{11} mode into the free space TEM_{00} mode over the frequency band of 90–100 GHz with a reflection better than -30 dB and a coupling efficiency of ~99.4%**

I. Corrugated Launcher and Window

A W-band gyrotron traveling wave amplifier (gyro-TWA) and gyrotron backward wave oscillator (gyro-BWO) [1] based on a cusp electron beam source [2-4] and a helically corrugated interaction region (HCIR) [5] have been developed to provide a continuously tunable source with a continuous wave (CW) power output of ~5 kW and ~10 kW respectively. The gyro-TWA was simulated to have a 3 dB frequency bandwidth of 90–100 GHz while the gyro-BWO demonstrated a tuning range of 88-102.5 GHz and has achieved an output power of 12 kW [6]. The fundamental operating mode in the gyro-TWA and BWO is an elliptically polarized TE_{11} mode. To provide a radiation source that is suitable for applications an output system must be implemented to convert the TE_{11} to a quasi-optical mode, which is preferable for coupling with external applications. One method of achieving this is by means of a corrugated mode converting horn [7]. This transforms the fundamental TE_{11} mode within the gyro-TWA to a hybrid mode that is generally accepted to consist of 85% TE_{11} and 15% TM_{11} (by power) and is closely coupled to the fundamental free space Gaussian mode (TEM_{00}) [8]. This Gaussian radiation beam is then free to pass through the vacuum window [9] unperturbed by the outer structure of the window with a very low reflection. Using this type of corrugated mode converting horn in favor of more conventional beam-wave decoupling methods can be advantageous due to the increase in performance that it makes possible. This method gives both a greater bandwidth and the capability to provide a source that is continuously tunable over this bandwidth. In designing the launcher system, including the window, the primary consideration was the reduction of the reflection. This is a critical parameter for the stable operation of the gyro-TWA, due to the possibility of stimulating unwanted oscillations by backward travelling waves. It was found that the optimal reflection was best achieved using a $\sin^2$ profile [10] for the horn and by constructing a multi-layer vacuum window, which can effectively transmit the radiation over a large bandwidth. This initial profile, as well as the window structure, were optimized using a mode matching method and numerically validated by comparing the aperture fields with the fundamental Gaussian mode.

II. Experimental Results

This horn was constructed by the electroforming of copper onto an aluminum substrate and the completed millimeter wave component was tested on a W-band Anritsu 3738A VNA. The reflection from the horn was determined by one port measurement where microwaves were radiated into free space. Far-field measurements of the horn showed that the -30 dB edge was within a half angle of 14.5 degrees and the pattern showed more than 99% of the output power was within 29 degrees. The simulated results demonstrated that the horn is coupled to the fundamental Gaussian with an efficiency of ~99.4% and measured results show a reflection of better than -30 dB.

III. Summary

A high performance mode converting horn and window combination has been developed to produce a Gaussian output with a reflection over the 90-100 GHz bandwidth of better than -30 dB. This second generation horn includes an output window, which allows for better integration with the gyro-system and has a coupling between the HE_{11} mode and the free space Gaussian mode of 99.4 % with the window.

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