CHAPTER 6

SUMMARY, CONCLUSION AND FUTURE SCOPE

6.1 Summary and Conclusion
6.2 Scope for Further Studies

6.1 Summary and Conclusion

The evolution of HPM sources using vacuum tubes was primarily for defence application, but from the past few decades researches are going on for the non-defence applications also. These non-defence applications enhance the requirement of compact and lightweight HPM systems. Although for the microwave generation devices like high power electronic devices, it is difficult to produce GW power level. However, HPM sources like MILO, RBWO, RKA, Relativistic Magnetron and VIRCATOR are efficient in generating HPM. These sources radiate RF power in the azimuthally symmetrical modes TM_{01} or TEM modes, and the radiation pattern of such modes contain null at the axis of propagation. Thus, there is an essential requirement of the mode converters for the HPM systems to interface such HPM sources with the system. Therefore, during the past few decades, considerable research interest has been aroused in the development of a mode converter compatible with HPM sources and to convert TM_{01} mode to TE_{11} mode, where the TE_{11} mode radiation pattern has its boresight along the axis of propagation. The SWG mode converter is well recognized as they designed by separating coaxial waveguide with using axial radial metallic plates. As HPM systems have important applications in HPM weapons (E-bomb), space beam drove a rocket by RF propulsion, solar power transmission through space using HPM, radar capability enhancement and rebuilding Ozone layer. By using SWG mode converter the applications on HPM systems require maximum RF power in the direction of propagation. Among the variety of mode converter available, the SWG mode converter still finds its dominance for delivering high convergence efficiency, high power capability, along with easier design and development procedure and this is an area where the mode converters based on gradual discontinuities are not able to compete. There exists a power handling capability gap in between the all metal and dielectric loaded SWG mode converter.

Inside the SWG mode converter, metallic plates separate coaxial waveguide in the sectoral region having sectoral angle π, π/2 and π/2 rad. Upper semicircle consists of SWG_{π} and lower semicircle consist of two $SWG_{\pi/2}$. Due to different axial propagation constant propagating RF wave encounter phase difference at the end of sectoral region. *TEM* mode in the coaxial waveguide has electric field orientation either in outward or inward direction along with all azimuthal positions. Thus, at the input side of sectoral region the mode in SWGs is TE_{11} mode, and electric fields are considered in outward direction across all azimuthal position over the coaxial waveguide. So for SWG_{π}, electric field orientation is in upward direction and for $SWG_{\pi/2}$ in downward direction. By taking a proper length of the sectoral region to achieve π rad phase difference, at the end of this region electric field has same orientation and in result they combine to form TE_{11} mode over the coaxial waveguide. The advantage of this mode conversion is based on its application where it helps in targeting an object or receiver using TE_{11} mode radiation pattern.

To design a TM_{01} to TE_{11} mode converter, design and fabrication complexity becomes a crucial issue. The literature survey has been made for the mode converter designs and found that such converter contains gradual discontinuity and are very complex in design and fabrication as well as are axially aligned. In a class of mode converter based on axial discontinuity, except folding SWG type, all other mode converters are less complex in design. In this class of mode converter, SWG mode converter is relatively simpler in design, HPM capable and compact in size.

As in the literature, Chittora *et al.* (2015) have discussed beam stability; however it was for dielectric loaded mode converter. There was a challenge to achieve the beam stability in all metal SWG mode converters and was developed and described in Chapter 3. The complete design procedure of SWG mode converter for conversion of TM_{01} to TE_{11} mode was presented in this chapter. The proposed design in this chapter has an advantage of the stubs free design. The position of *Plate1* introduces the beam stability due to nullifying orthogonal TE_{21} mode generated from SWGs to the coaxial waveguide. Also, the length of *Plate1* provides impedance matching too. To validate our design methodology, the simulated results of reflection loss and radiation pattern were compared with those of the experimental results and found in close agreement. The proposed all metal SWG mode converters, its analysis, and design methodology would be useful for the HPM system developers.

Further rigorous analytical study of the SWG mode converter using computational modelling technique other than available commercial simulation software is found as an essential requirement. An effective analytical method in designing and optimizing SWG mode converters reduces the simulation time, parametric analysis and increases the design accuracy in its fabrication, and for this mode matching technique (MMT) has been used. In mode matching analysis the amplitude of each mode affects the excitation of modes in the adjacent region or sub-region according to their boundary conditions. This shows the importance of MMT, unlike other numerical methods. The mode matching analysis has three major steps: an evaluation of field constants, expressing coupling coefficients and obtaining a generalised scattering matrix (GSM). Both the simulated and mode matching analysis results show mode conversion efficiency, higher than 98%. Also, the reflection loss analysis using MMT shows more accurate result and found good in agreement with the measured results.

In the all other conventional SWG mode converter design and proposed design in Chapter 3, there is an inner conductor which introduces an increase in weight of the SWG mode converter. If it is required to reduce the SWG mode converter the conventional model required design modification. In Chapter 5, the design proposed removal of inner conductor in the mode converter design converts TM_{01} mode to TE_{11} mode using CSWG. The conversion efficiency of this mode converter is more than 90% over the frequency range 2.97-3.02 GHz, and the total power transferred more than 90% of input power over the frequency range 2.89-3.04 GHz. This mode converter can use for HPM systems at megawatt level microwave power. The proposed mode converter is lower in weight with high return loss. The other advantages are a linear, compact structure and High Power handling capability.

6.2 Scope for Further Studies

The SWG mode converter is an essential component for the HPM systems; the utility of mode converter depends upon the HPM source as well as a particular system application. In the future, application-based study of the SWG mode converters with different HPM sources will be useful for further research targeted to particular HPM system. This will allow choosing this HPM component for the HPM systems. In addition, HPM system requires an efficient RF windowing which also capable of focusing the radiated beam. Such windows are one of the areas of further investigation and require compatibility with the SWG mode converter design.

The mode matching analysis of SWG mode converter was presented in chapter 4. The same study can be extended for other n-furcation of the coaxial waveguides too. Also modified computational analysis having mode matching along with other 3D computational programming is required to analyse the proper EM fields combining positioned azimuthally.

In future, such design can be studied to keep the HPM system, thermally stable for effective performance. Thermal analysis of SWG mode converter will also be required because thermal deformation of metallic structure could affect the axial propagating constant and may result in deterioration of conversion efficiency as well as a decrease in reflection loss.