Effect on Noise Power Output of X-Band Argon Gas Discharge Tube Noise Source with Different Argon Gas Pressures.

Narendra Y. Pawar, S.A.Gangal, A.D.Shaligram
Department of Electronic Science, Savitribai Phule Pune University, Pune India
narendrapawar19722003@yahoo.com

Abstract: Gas discharge tubes containing inert Argon gas at 8,16,32,64,128,256 torr respectively when excited with appropriate DC voltages produces steady state gas discharge plasma containing light radiation and wideband microwave noise. Individual tube coupled with X-band microwave cavity or waveguide with appropriate coupling factor and volume of gas discharge produces wideband white noise. Generated noise has certain noise amplitude and frequency spectrum defined by cut-off frequencies of X-band waveguide. Different Argon pressure tubes produces different noise amplitudes and frequency spectrums, these are studied for obtaining optimal gas pressure for discharge tube that generates flat white noise in X-band microwave region.

Keywords: Argon Gas, Gas Pressures, Gas Discharge, Noise Power, Noise Spectrum, X-Band, Spectrum Analyzer Method, Excess Noise Ratio (ENR).

Introduction: Gas discharge depending upon the type of gas, gas pressure, excitation power, geometry of enclosure produces a discharge plasma. This discharge plasma might contain gamma rays, X-rays, ultraviolet rays, white light, infrared rays and broad spectrum of radio frequencies in microwave, UHF, VHF, HF regions. Example of such gas discharge is Sun, Stars, Galaxies and Nebulas. Type of radiation produced in gas discharge plasma is widely studied and discussed by [1] Bremsstrahlung. Thus all celestial bodies above 0º Kelvin produces broadband noise in RF spectrum that contributes to the input noise into the communication systems antennas those are pointed towards open sky. Gas discharge tubes using inert gases like Argon, Neon, Krypton and Xenon are widely used for lighting purpose. These same tubes with appropriate dimensions could be used for making gas discharge noise sources [2]. Few companies like LCC [3] produces gas discharge tubes for noise sources in various microwave frequency bands. Datasheets of commercially manufactured noise discharge tube mentions dimension, excitation voltage, current, and approximate Excess Noise Ratio (ENR) values tube can produce when used with mentioned microwave waveguide mount. Excess noise generated by gas discharge plasma tube is dependent on type of gas used in discharge tube, pressure of gas used, dimensions of the tube, excitation power used and coupling of discharge tube to microwave cavity. This paper reports the effect on noise output power spectrum with different Argon gas pressure tubes used in X-band (8.2 to12.4 GHz) microwave region with fabricated waveguide mount for obtaining optimal gas pressure tube for generating flat white noise in X-band microwave region.

Design and Discharge Characteristic of Fabricated Argon Gas Discharge Tube: For studying effect of gas pressure on noise output Quartz glass gas discharge tubes of 10mm diameter and 320mm length with pure Argon gas pressure of 8,16,32,64,128,256 torr respectively are fabricated with tungsten electrodes attached on both sides. Plasma discharge is produced by electrons striking the gas atoms when excited with appropriate voltage and current. For this to happen, the mean free path of electrons has to be reasonably long but shorter than distance between the electrodes. The breakdown voltage for plasma discharge depends nonlinearly on products of gas pressure and electrode distance according to Paschen's law. Gas discharge plasma do not readily occur at both too low and too high gas pressure. Fig.1 shows Paschen curves for widely used discharge tube gases.

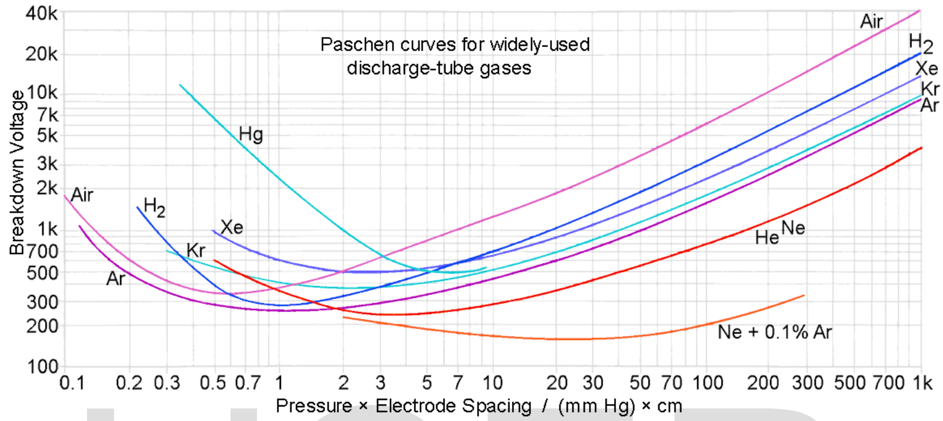


Fig.1 Paschen curves for widely used gases for discharge tubes.

From the graph of fig.1 it is seen that if the electrode distance is kept constant the discharge in tube is dependent on the gas pressure. To generate plasma discharge at too low pressure or at too high pressure very large potentials are needed. Paschen found that breakdown voltage was described by the equation

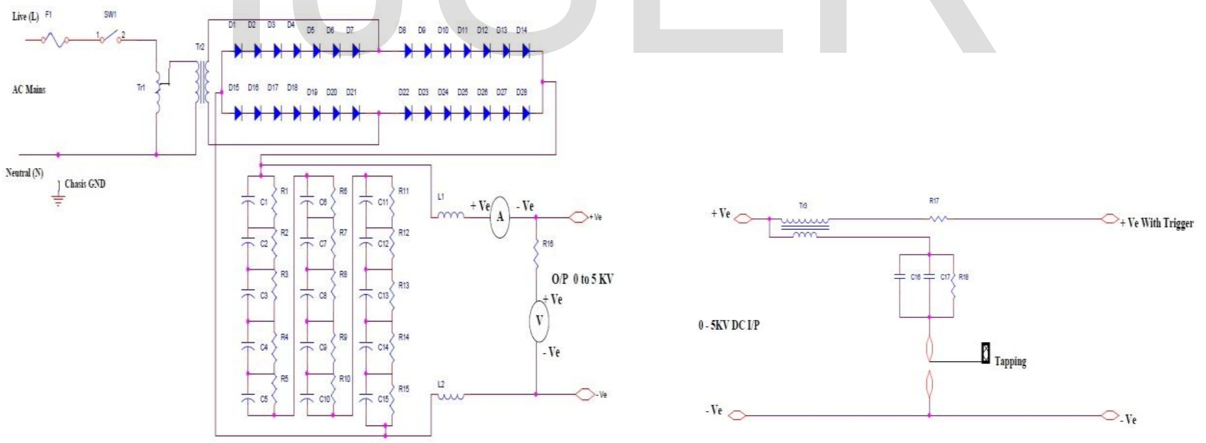
$$V_B = \frac{B_{pd}}{\ln(Apd) - \ln\left[\ln\left(1+\frac{1}{\gamma_{se}}\right)\right]}$$

Where V_B is breakdown voltage in Volts, p is the pressure in Pascal, d is the gap distance in meters, γ_{se} is the secondary electron emission coefficient, A is the saturation ionization in the gas at particular E/p (electric field/pressure), and B is related to the excitation and ionization energies. The constant A and B are determined experimentally and found to be roughly constant over restricted range of E/p for any given gas. The graph of this equation is the Paschen curve. By differentiating it with respect to pd and setting the derivative to zero, the minimum voltage can be found. This yields

$$pd = e^{(1-B)}$$

Thus the noise generated by discharge plasma is dependent on the gas pressure in tube, distance between electrodes and type of gas used and excitation energies. In this discussion we have kept distance between discharge electrodes constant (300mm) , diameter of the tube constant (10mm), type of gas to be the same (pure Argon) , same excitation energies only parameter changed is pressure of gas by fabricating tubes at different gas pressures (from 8 to 256 torr). As seen in fig.1 curves to get gas discharge plasma for different pressure different voltages are needed , to full fill this condition a variable power supply with suitable high voltage momentary trigger is fabricated. Fig 2 shows circuit diagram of high voltage power supply with ht trigger arrangements.

Design and Construction of Waveguide Plasma Tube Noise Head Mount: Argon tube noise source consists of 45cm long WG16 waveguide with X-band size flanges attached for coupling it to waveguide termination and waveguide to 50Ω flange converter. This waveguide is drilled on E-plane at centre with 13mm drill at the angle of 15º for inserting Argon tube in waveguide. Drilled upper and lower surfaces of waveguide are fitted with round circular hollow brass pipe pieces sliced at 15º to cover complete length of Argon tube. These two pieces are soldered to WG16 waveguide in such a fashion that Argon tube could be very easily inserted into the waveguide. Ends of circular brass pipes are fitted with Teflon caps with two small holes for running electrical connections and holding Argon tube firmly into waveguide mount. Fig.3 shows arrangement for X-band gas discharge noise head with Argon tube inserted and the photograph of fabricated noise source head using Argon tube, also the fabricated tubes of different gas pressures. One flanged end of noise head is attached with ferrite waveguide terminator and another is connected to waveguide 50Ω N type coaxial transition for carrying out various measurements. Waveguide terminator is used for appropriate matching and to avoid reflections of noise power generated in that direction. Once Argon tube is installed firmly in waveguide mount it is excited with 5kV DC power supply having high voltage momentary trigger to start gas discharge. Once the gas discharge is started current through discharge tube is adjusted by dimmer stat to appropriate watts of power for obtaining steady state discharge. When steady state discharge is obtained tubes consume about 40 to 45 watts of power. Sustaining voltage and current through tube will depend on the gas pressure inside the tube.



R1-R15-120kΩ,R16-6.6MΩ,R17-22k,50W,R18-100kΩ,C1-C15-330µF,450V,C16-C17-0.047µF,4kV,L1-L2-100µH,.5A,D1-D28-1N5408,Tr1-0-270Dimmerstat,Tr2-230VPri/4kVSec Transformer,Tr3-Mico EHT ignition coil 12VPri/20kV Sec.

Fig.2 High voltage Power supply circuit and HT trigger circuit for exciting gas discharge tube.

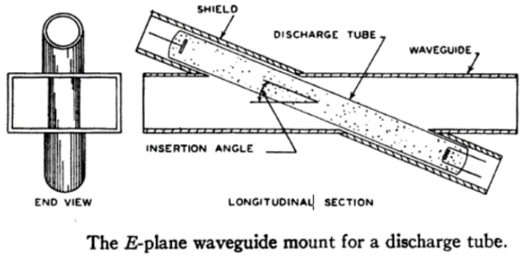
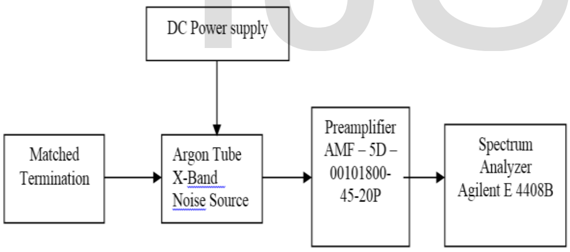


Fig.3 Arrangement for tube mount and photograph of complete noise head mount for X-band with different prssure Argon tubes fabricated (8,16,32,64,128,256 torr)

Measured Observations and Results: For carrying out measurments Argon gas discharge tube is mounted in X-band waveguide mount and excited with appropiate voltage and current to obtain steady state discharge. Once the steady discharge is obtained noise source head is kept on for five minutes to reach steady state temperature. Measurements of noise power output is carried out by connecting noise source N type connector to spectrum analyser(Agilent E 4408B) with external preamplifier(Narda AMF-5D-00101800 45-20P). Fig.4 shows block diagram of noise measurement setup with photograph of measurement setup.



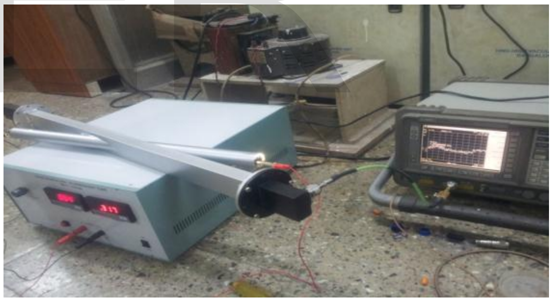


Fig.4 Block diagram and experimental set up for Spectrum Analyzer method of noise power measurement.

Measurements are carried out by putting appropriate pressure argon tube into noise head mount and powering it up by applying DC voltage between 2kV to 3.8kVand ht trigger pulse momentarily to start gas discharge. Once the gas discharge starts the current through tube is adjusted between 10mA to 20mA so that a steady discharge is sustained by tube with power consumption not exceeding about 45watts. All different pressure tubes are tested for their noise power outputs by inserting them into same noise head sequentially by keeping spectrum analyser measurement setting same for every measurement. Fig.5(a to f) shows spectrum plots of measured noise power in X-band generated by 8,16,32,64,128,256 torr Argon tubes respectively.

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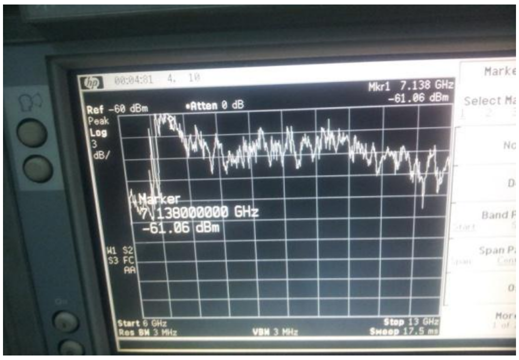

Fig.5(a) Spectrum of 8 torr tube

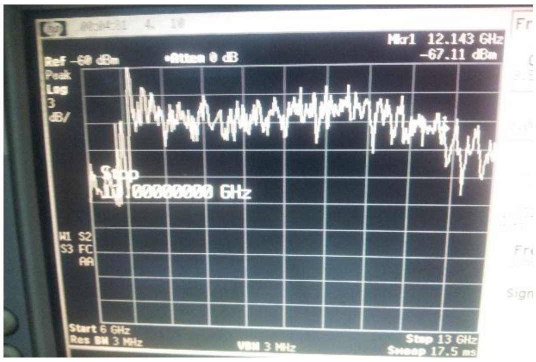

Fig.5(b) Spectrum of 16 torr tube

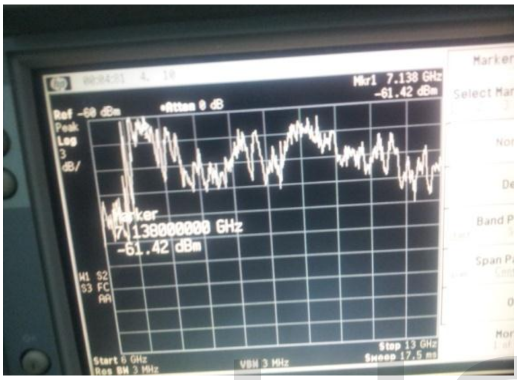

Fig.5(c) Spectrum of 32 torr tube

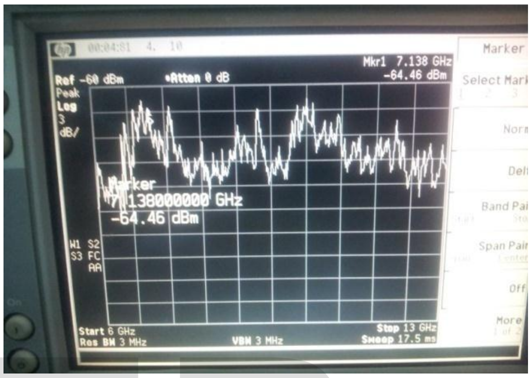

Fig.5(d) Spectrum of 64 torr tube

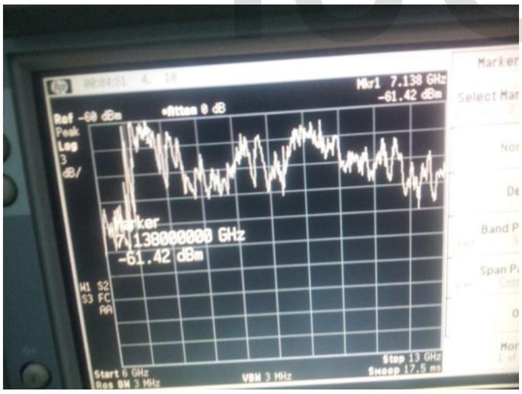

Fig.5(e) Spectrum of 128 torr tube

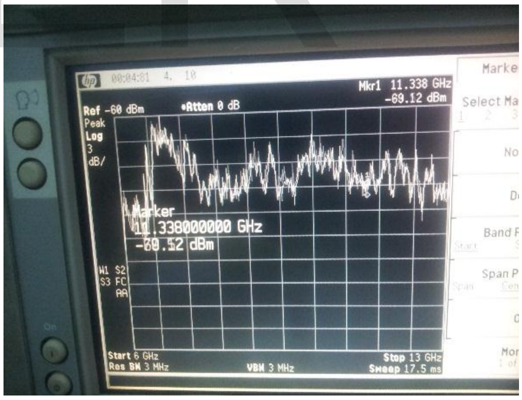

Fig.5(f) Spectrum of 256 torr tube.

Noise floor of spectrum analyzer at X-band is flat and around -75 to -76dBm. When noise source with different Argon pressure tubes replaced , connected to spectrum analyzer average noise output of every tube was found to be around -63to-64dBm. Observed noise output was having different spectrums depending upon the prssure of argon gas contained by the tube. Higher gas pressure tubes have higher variations in flatness of noise output spectrum even though average output of all the tubes happen to be around the same. Percentile flatness of noise output amplitude sweep over 8.2 to 12.4 GHz frequency range for tested tubes(8 to 256 torr) are plotted and shown in Fig.6.

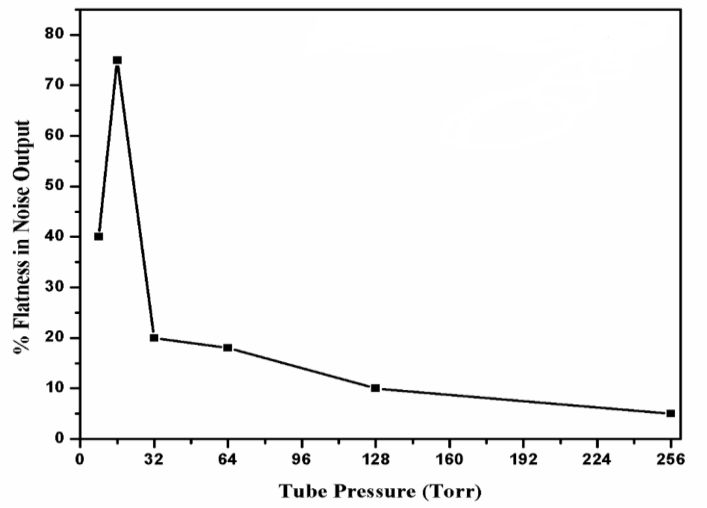

Fig.6 Variation percentile in noise output amplitude sweep flatness vs Argon gas pressure in tube.

Conclusions: By observing the specrum plots in Fig. 5(a,b,c,d,e,f) and Fig .6 it is found that the nature of noise generated by Argon gas discharge depends on the interactions of ions with number of gas molecules contained in the dischage tube. Too high gas pressure(25 to 256 torrs) generates intense discharge and noise generated has large variations in amplitude and essentially lacks the flatness of white noise. Too low gas pressure (1to10 torrs) generates very moderate discharge and generated noise has also large variations although lower than the high pressure, it also lacks the flatness of the white noise. Thus Argon gas tubes having very low gas pressure about 1 to10 torr and high gas pressure about 25 to 256 torr generates noise when excited, but are not suitable for making standard noise source. The noise generated by these tubes lack the essential flatness needed for standard noise source. Tubes having gas pressure of 14 to 20 torr generates steady and flat noise over almost entire X-band and has flatness required for using them as standard noise generating source. Calibrated noise source head with 16 torr Argon gas tube could be used as noise standard for entire microwave X-band to carry out various noise related measurments.

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