Concerning The Discussion On Low Noise Plasma Antennas, The Following Comments Are Pertinent.

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The material was an expansion of the work in the book, "Fundamentals of Statistical and Thermal Physics", by F. Reif, McGraw-Hill, 1965, pp 587-589 for the standard Nyquist's Theorem and pp 585-587 for the Wiener-Khintchine Theorem.

The mathematics derives the noise equation as;

$H = 4RKT$, where H is the noise spectrum as Volts squared per Hertz (not Watts), R is the resistance of the object in Ohms (not Ohms per unit length) , K is Boltzmann's constant in Joules per degree K, and T is the temperature in degrees K.

The book acknowledges that the equation is a low-frequency approximation, but states that this approximation is correct, since in metals the collision frequency is a terahertz.

The correction term found by Dr. Ted Anderson and later by Professor Igor Alexeff is;

$$H = 4RKT\left(\frac{1}{1+\frac{(2\pi\upsilon)^2}{\upsilon_{cc}^2}}\right)$$

Where υ is the frequency of the transmitter in Hertz, and υ_c is the electron-gas atom collision frequency in Hertz.

The factor of 2π is a numerical constant that arises from the Fourier Transform process.

To compare the noise in a given spectral region, we must obtain both R and υ_c for metals and for plasmas. We consider operation at 10 GHz (3 cm wavelength).

In metals, we already have υ_c from the textbook, Rief, which is 1 THz.

For the resistance, we assume a rod 1 cm square in cross section and 3 cm long. The resistance of copper is 1.692exp -6 ("Handbook of Chemistry and Physics"), so our metal antenna would be 5.076 exp -6 Ohm if skin depth were to be neglected.

Skin depth is given by

$$(\frac{2}{\sigma\mu\omega})^{\frac{1}{2}}$$

Where σ is the conductivity, μ is the permittivity, and ω is the angular frequency of the microwaves (radians per second or $2\pi\upsilon$ in Hertz).

The skin depth is 2 exp -5 cm. Hence the resistivity corresponds to a copper sheet 3 cm long, 4 cm wide, and 2exp -5 cm thick. This corresponds to a resistance of .063 Ohms.

The temperature of the copper is 300 degrees Kelvin.

For the plasma, we compute the collision frequency as follows. Using Cobine's book, "Gaseous Conductors", we find the pressure in a fluorescent tube to be a maximum of 2 mm hg. The electron-gas atom scattering cross section corresponds to an electron temperature of 1 electron-volt, is deep in the Ramsauer Minimum, and is found in Fig. 2.3. We find a mean-free-path of about 1 cm at a pressure of 1 mm hg. This gives a scattering cross section of 2.8 exp -17 cm squared (It is at the Ramsauer minimum.), at a pressure of 1 mm hg.

The electron velocity corresponds to 1 electron volt. The thermal velocity is $v = \sqrt{\frac{KT}{m}}$ where v is the velocity, K is Boltzmann's constant, T is the electron temperature, and m is the electron mass. Inserting the proper values gives an electron thermal velocity of 4.2 exp 7 cm per second. Using the atom density at s mm hg to be 7.02exp 16 per cc, we compute the collision frequency to be 82 MHz. Actually, if the tube is about 1 cm in diameter, the collision frequency at the wall exceeds this.

Concerning the resistance of the tube, Cobine gives the voltage drop for a 9 inch tube to be 45 and for a 48 inch tube to be 108. Subtracting these to get rid of the cathode drop and to find the voltage drop on the positive column, we get 1.62 volts per inch, or 0.638 volts per cm. The current ranged from .15 to .42 Ampere. Since the tube has essentially a voltage drop independent of current, we use the .42 Ampere value. This yields a resistance of 1.52 Ohms per cm. For a 3 cm long column of plasma, we have 4.56 Ohms.

Computing the noise figure in volts squared per Hertz, the metal gives us 1.04 exp -21.

For the plasma antenna at 10 GHz, we obtain 4.29 exp-24.

Thus in this frequency range, the noise in the plasma antenna is much less than the metal antenna. Of course, at low enough frequencies, the inequality is reversed, but we can address that by reducing the gas pressure in custom made plasma tubes.

Note that we used the upper limit for gas pressure in this report on the plasma tube. In the patent application, pressures two thousand times lower have been used. (US Patent 1,790,153). Using the lowest pressure would reduce the plasma noise by about a factor of 2000.

Keep in mind that our analysis has been and is for a fluorescent lamp. We have made plasma antennas out of florescent lamps because they are inexpensive and it shows that we can do research and development and build prototypes of the plasma antenna technology cheaply.

When we ruggedize our plasma antennas with custom made plasma tubes, we can make the gas pressure inside the plasma tubes much less than in a fluorescent bulb and lower the frequency at which the plasma antenna thermal noise is equal to the metal antenna thermal noise.

Using the highest gas pressure in a florescent tube of 2 millimeters, the frequency at which the plasma antenna and the metal antenna have the same thermal noise is 1.27 GHz. Using the lowest gas pressure of a fluorescent tube of 1 micron, this cross over frequency at which the plasma antenna thermal noise and the metal antenna thermal noise are equal is much lower. Above the cross over frequency where the thermal noise of the plasma antenna and the metal antenna, the plasma antenna thermal noise drops rapidly.

As stated above, custom made plasma tubes can be made such that pressure is much lower than in a fluorescent lamp. This would give a number in which the thermal noise of the plasma antenna and the metal antennas are equal much lower than 1.27 GHz antenna frequency.

Again, we have used florescent tubes to make plasma antennas because this has been an inexpensive way to do our plasma antenna research and development. With further funding, we will develop and make custom made plasma tubes which are rugged and have lower noise than metal antennas over very wide frequency range.