# The Inverse Corbino Effect applied to the Strömerzeuger

**Cyril Smith, September 2013**

## 1. Introduction

The data revealed in the UK National Archives shows that Coler, in replicating the Strömerzeuger, used three windings on his iron-cored electromagnets with the outer two wound in opposition to the centre one. I have previously made the suggestion that this was to linearize the magnetic field in the iron because I was fixated on the idea that the overunity came from gaining energy from the electron precessions and to get any hope of coherence the field must be linear. While recently reviewing this evidence I have come to realize that this interpretation is completely wrong. To obtain a linear field within the core requires the outer windings to supply greater ampere-turns than the inner ones *in the same winding direction*. The arrangement used by Coler creates maximum *non-linearity*, i.e. maximum leakage flux along the rod. So I turned my thoughts to how this characteristic could be used to effect, and decided that the Hall-Effect might play its part.

The Hall-Effect in ferromagnetic conductors has only recently been analysed in a satisfactory way, in the early days it was found to behave differently from that of non-magnetic material where it became known as the Anomalous Hall Effect (AHE). Of significance is a Hall voltage being present when the applied field is zero that stems from internal magnetization, thus the classical Hall resistivity (based upon the sideways Lorentz force of charge carriers moving in a magnetic field) requires an additional term to account for this. To complicate things even more that additional term has itself two contributions, one intrinsic (not related to the applied magnetic field) and the other extrinsic (determined by the external magnetic field). Not only can the additional term be greater than the classical one, it can be negative as is the case for iron at low magnetization levels.

## 2. The Corbino Effect and Inverse Corbino Effect

The Corbino Effect, which is related to the Hall Effect because the same physical principles apply, has been known for over 100 years. Essentially the Corbino system is a circular Hall plate where the induced Hall voltage appears in a closed circuit, thus the voltage disappears to be replaced by a circular current. The input current is radial. This is summarized in Figure 1.

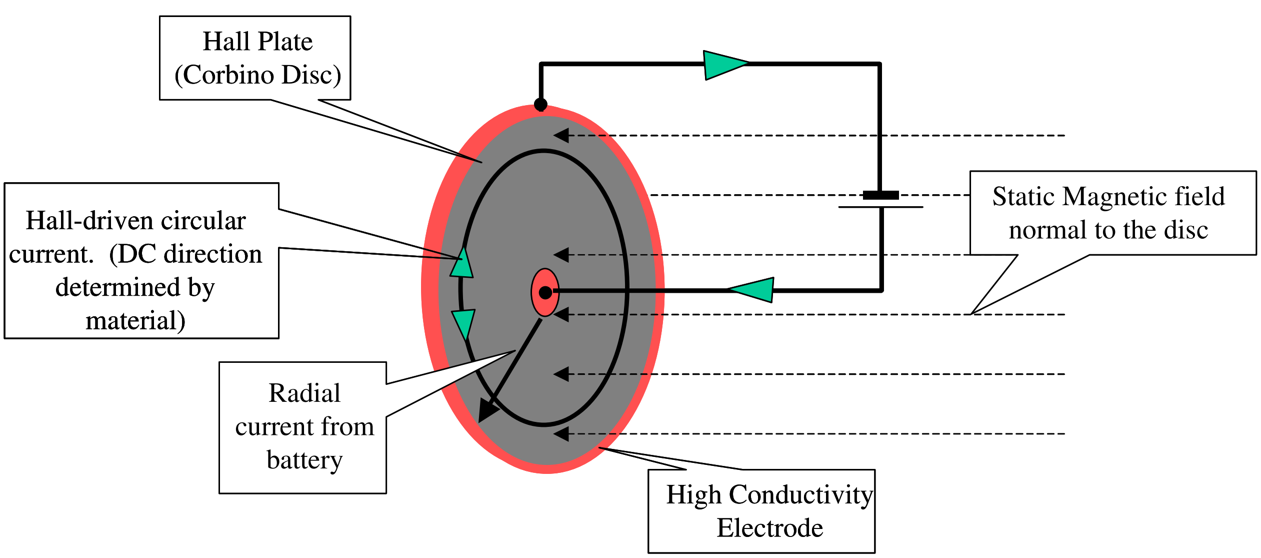


**Figure 1. The Corbino Effect**

For the *Inverse* Corbino Effect (ICE) the input is a closed circular current whence the output is a Hall voltage existing between the disc center and its outer periphery. The closed current (eddy current) has to be induced by a changing magnetic field normal to the surface, hence the ICE only applies to alternating inputs and outputs. This alternating magnetic field is in addition to and can be small compared to the DC magnetic field needed to create the radial Hall voltage. Note that the basic Hall effect is inversely proportional to the thickness of the disc, and at RF the eddy current is restricted by the skin effect to flow only near the surface, hence the RF Hall voltage could occur on the surface of thick material. To the author's knowledge this inverse Corbino effect has never been used. It is summarized in Figure 2.

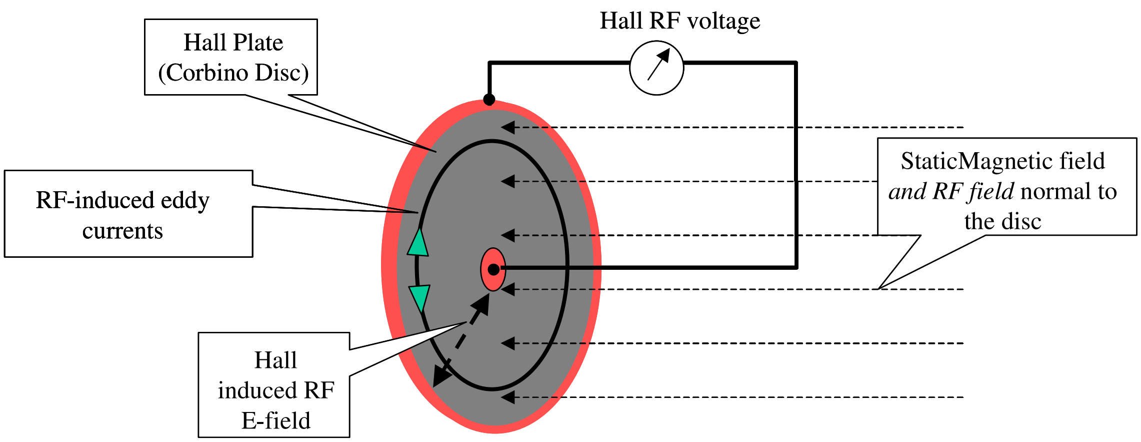


**Figure 2. The Inverse Corbino Effect**

## 3. Cylindrical Geometries

In the Strömerzeuger the ferromagnetic geometry is not a disc but is cylindrical. The Cylindrical Corbino Effect applies when the Hall Plate becomes a thin walled cylinder as shown in Figure 3. This requires magnetic field lines to pass through the walls and this divergent field can be provided by a permanent magnet at one end of the cylinder, or opposing magnets at each end. Longitudinal current in the cylinder induces, via the Hall Effect, circular current around the cylinder.

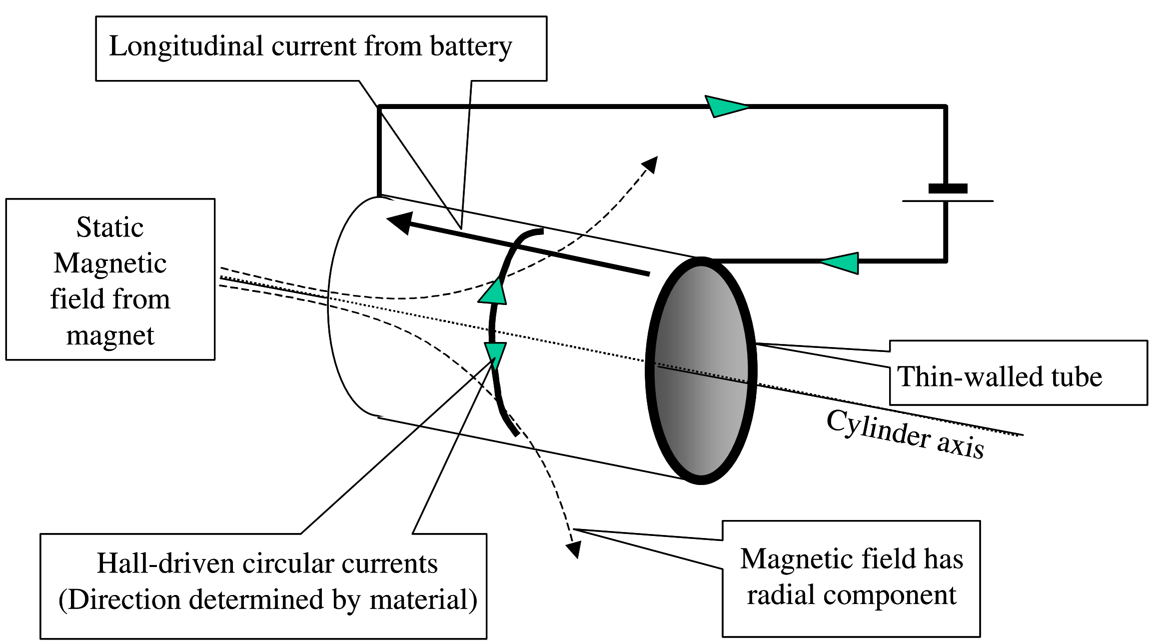


**Figure 3. Cylindrical Corbino Effect**

For the Cylindrical Inverse Corbino Effect (CICE) a longitudinal RF field drives eddy current around the cylinder. At the frequencies used it is known that the skin depth is small, so any RF currents flowing will be within a thin region at the surface, effectively in a thin-walled cylinder. If there then exists a DC magnetic field crossing that surface the Hall effect will generate an E field along the axial direction producing a RF voltage, as shown in Figure 4.

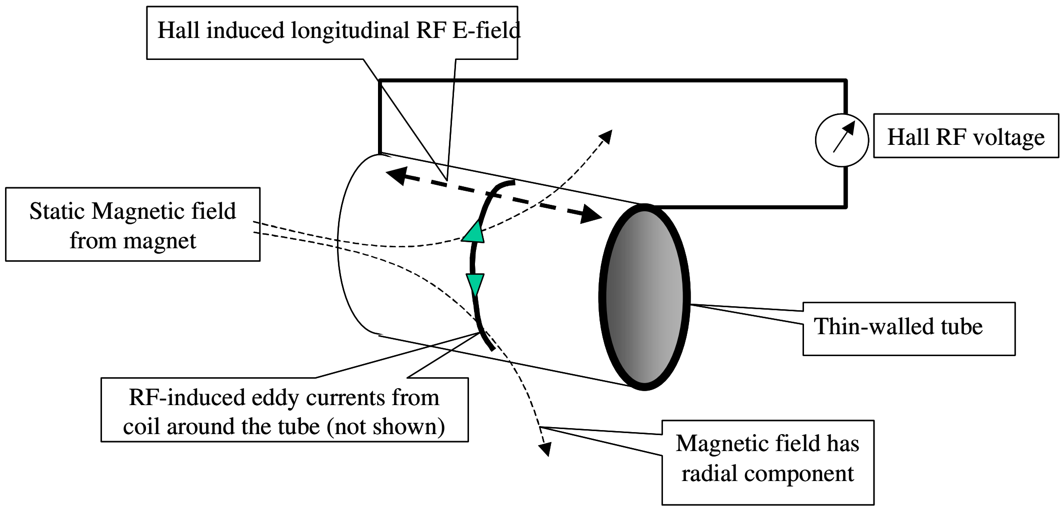


**Figure 4. Cylindrical Inverse Corbino Effect**

This could well be the anomalous voltage that drives the Strömerzeuger into self-oscillation. It may be noted that Coler used magnetized piano wire connected to one end of the Fe core via something that looked like a lathe collet but is in fact a flux concentrator. Figure 5 shows an FEMM simulation for a small diameter magnet connected to a larger rod in this manner.

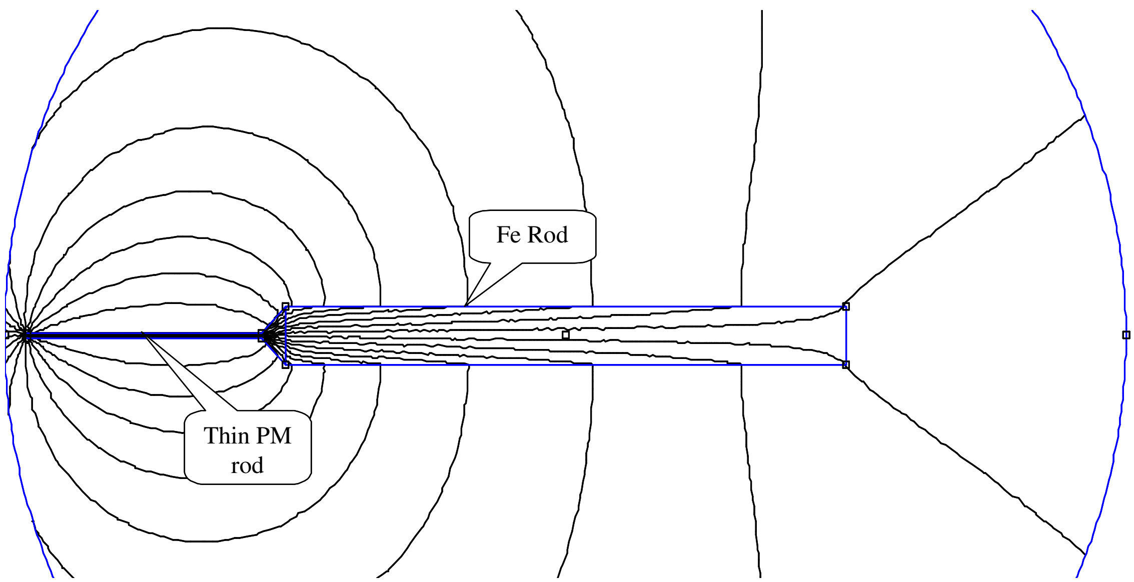


**Figure 5. Thin Permanent Magnet connected to Fe Core**

Note the flux lines emanating radial to the cylindrical Fe surface that, for induced RF eddy currents around the cylinder, create additive RF Hall voltage along the cylinder. As is well known permanent magnetism is equivalent to very large values of coil current, hence it is posited that Coler's particular coil arrangement on the rods is not the primary DC magnetization effect, and is used merely to fine-tune the operation of the system. It should be possible to eliminate the need for those electromagnet coils and just use the PM supplied flux.

## 4. Calculations

The skin effect allows us to imagine all the RF current flows within a thin surface layer of depth $\delta$ given by $\delta = \sqrt{\dfrac{2}{\omega\sigma\mu_R\mu_0}}$ where $\sigma$ is the conductivity, $\mu_R$ the relative permeability of the conductor and $\mu_0$ free space permeability. Hall voltage $V_H$ across the cylinder ends is related to the surface current $I$ flowing around the cylinder by $V_H = \dfrac{R_H I B_n}{\delta}$ where $R_H$ is the Hall coefficient and $B_n$ is the magnetic field normal to the surface. If we have a coil of $N$ turns wound around the conductive Fe rod and carrying a RF current $i$ the induced surface current $I$ will negate the applied $Ni$ ampere turns hence $|I| = Ni$. Then by substitution of $\delta$ and $I$ the RF Hall voltage becomes

$$V_H = R_H N i B_n \sqrt{\frac{\omega\sigma\mu_R\mu_0}{2}}$$

For Fe $\sigma \approx 10^7$, $\mu_R \approx 10^4$ and $R_H \approx 10^{-9}$. If we use 100 turns, assume an average value of $B_n$ to be 0.1T and take a frequency of 200KHz we obtain a RF Hall voltage of 2.8mV for every ampere of coil RF current. Putting the rod in series with the coil yields an effective induced resistance of ±2.8mΩ, depending on the polarity of the series connection. The negative value is of interest since that represents an energy source and if the magnitude exceeds the positive resistance losses the device can self-oscillate.

## 5. Experiments

For experimental purposes it is not necessary to reproduce the complicated Strömerzeuger circuit. A simple experiment using an iron rod with a magnet attached to one end will produce leakage flux along its length that is radially unidirectional. If that is placed within a coil that has been resonated with a capacitor to the claimed 180KHz frequency, with the iron rod included in the circuit wiring, it should be possible to look for Q enhancement or degradation when the magnet polarity is reversed. If that happens it is indicative of the Hall effect being present, then it may be possible to embark on a process of adjustments to gradually improve the enhancement to the point of self-oscillation. Such adjustments would almost certainly involve the iron material but at least there would be a test-bed for exploring the effect of different purities or treatments. Alternatively the RF Hall voltage along the rod could be isolated and measured, then its phase noted with respect to the driving RF. A reversal of the PM should create a 180 degree phase change.