Sensing & Control – Test & Measurement

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TMS Gen II FCC certification testing – Worst case model identification

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Honeywell

Introduction:

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- TMS9000 is a torque measurement sensor that works on the principle of wireless telemetry.
- This type of device is classified as intentional radiators. The intentional radiation (carrier) in this case is at 13.56MHz.
- As per FCC rules, intentional radiators have to comply with FCC part15C.
  - Sec 15.207 Conducted emissions (150KHz to 30MHz)
  - Sec 15.209 Radiated emissions (1.705MHz to 30MHz & 30MHz to 1GHz)
  - Sec 15.223 or 15.225 Fundamental emissions (1.705MHz to 10MHz & 13.110MHz to 14.010MHz respectively.)
- For certification testing the worst case model would be tested in a FCC listed Lab and the results would be submitted to Elite (TCB) for certification.
- Based on the test results of the worst case model and the following justification (combination of theoretical & test results) Honeywell team requests certification for all the models/variants having smaller antenna size than the worst case model (largest antenna size).
- This document establishes that
  1. 225 size rotor is the worst case model.
  2. The change in coupling style can be considered as a class 1 permissive change.

Block Diagram of TMS9000 Gen II Torque Sensor:

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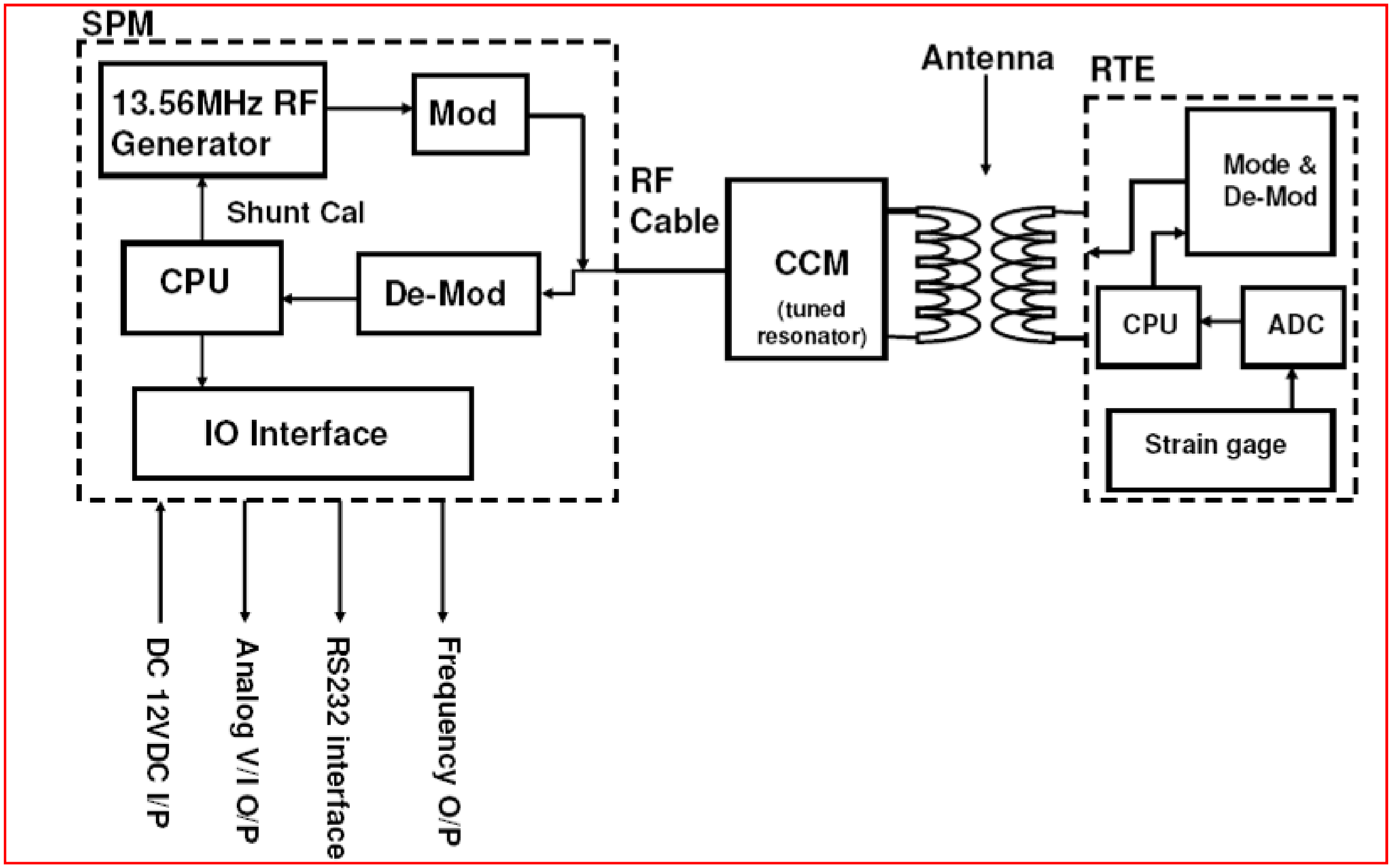

Theory of Operation/Technical Description:

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- Honeywell Torque Sensors are designed structures that perform in a predictable and repeatable manner when a torque is applied. This torque is translated into a signal voltage by the resistance change of strain gages, which are attached to the torque sensor structure. The change in resistance indicates the degree of deformation, and in turn, the torque on the structure.
- The strain gages are connected in a 4 arm Wheatstone bridge configuration which acts as an adding and subtracting electrical network and allows compensation for temperature effects as well as cancellation of signals caused by extraneous loading.
- When the torque sensor is rotating, a means must be provided to transfer an excitation voltage to the rotational element from a stationary surface, and also to transfer the torque signal from the rotational element back to the stationary surface. This is accomplished through the use of digital telemetry.
- The digital telemetry system consists of a receiver-transmitter module, a caliper-style coupling module (CCM) and a signal processing module (SPM). The receiver-transmitter module is an integral part of the torque sensor and is connected to the strain gauges and to the annular printed circuit board that contains the rotating antenna system. Within the receiver-transmitter module, the sensor signals are amplified, digitized, and are then used to modulate the radio frequency carrier wave that is detected by the antenna after being transmitted across the air gap by the caliper coupling module. That same carrier wave is rectified to provide power to drive the strain gauges and the electronic components in the module, which is managed by a miniature microprocessor.
- The caliper coupling module connects to the signal processing module via a simple tri-axial cable. The detector circuitry in the signal processing module recovers the digital measurement data from the torque sensor and passes it to the second microprocessor for scaling and linearizing.
- The third microprocessor provides the drive to the two analog outputs, as well as the standard digital interfaces and the optional digital interface modules. Extensive facilities are provided in software for setup and configuration of the complete system.

TMS9000 Coupling style and Torque measurement ranges:

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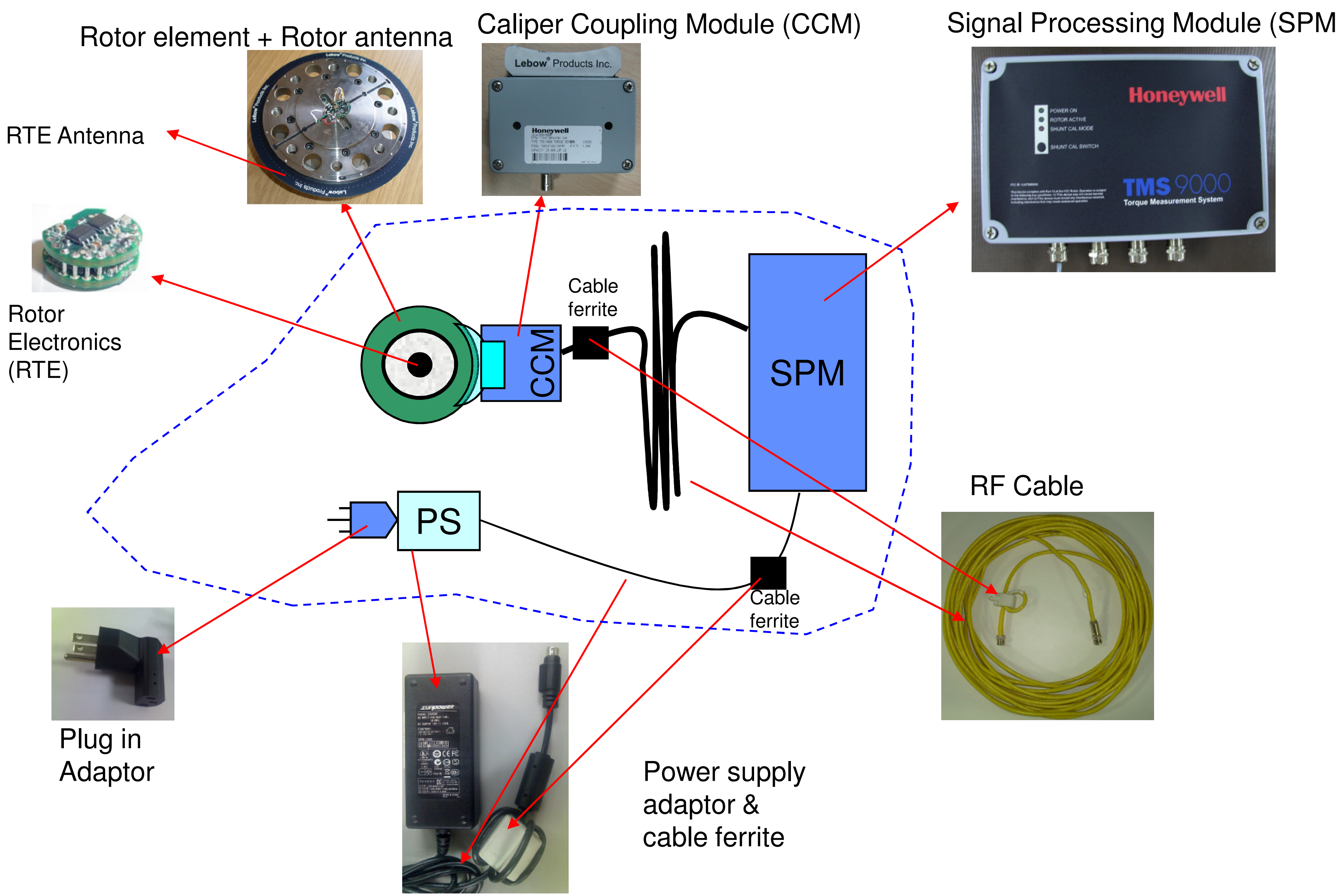
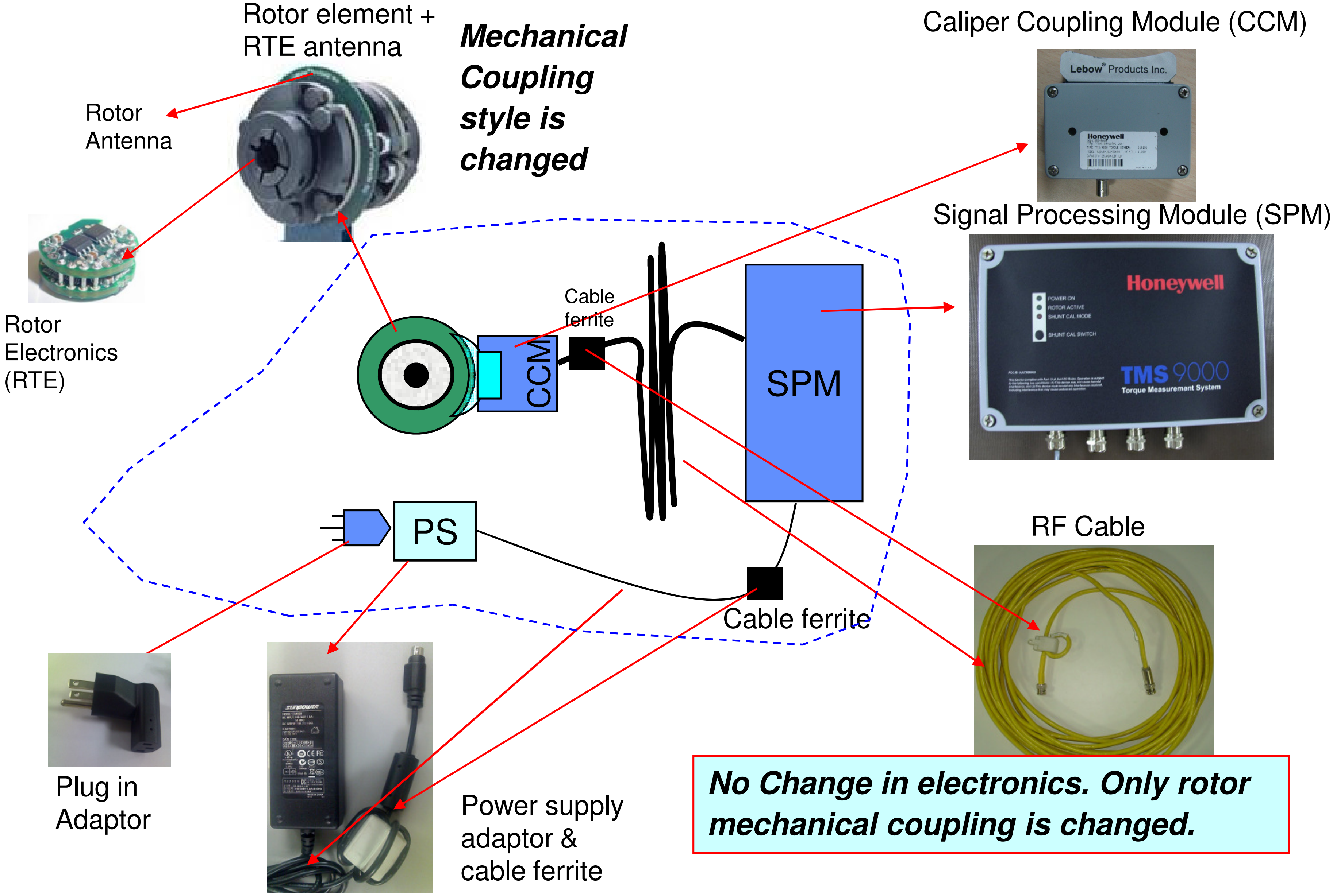
- There are 3 coupling styles offered by Honeywell for the TMS Gen II product line
  - Flange to Flange
  - Integral Coupling
  - Shaft to Shaft
- Each coupling style can have up to 6 rotor sizes (65, 90, 120, 150, 180 & 225).
- 65 size is the smallest rotor size and 225 size is the largest rotor size.
- The electronics (SPM, RTE & power supply) used in all the coupling styles/rotor sizes is the same.
- The only variable between the rotor size is the diameter of the sensing element on which the strain gage is mounted, Rotor antenna and the caliper coupling module.
- 65 size has the smallest element, rotor antenna and CCM size.
- 225 size has the largest element, rotor antenna and CCM size.
- The following 3 slides show the setup of the 3 coupling styles.

94000 Gen II Setup (Coupling Style: Flange to Flange)



94000 Gen II Setup (Coupling Style: Integral Coupling)

Honeywell



No Change in electronics. Only rotor mechanical coupling is changed.

94000 Gen II Setup (Coupling Style: Shaft to Shaft)

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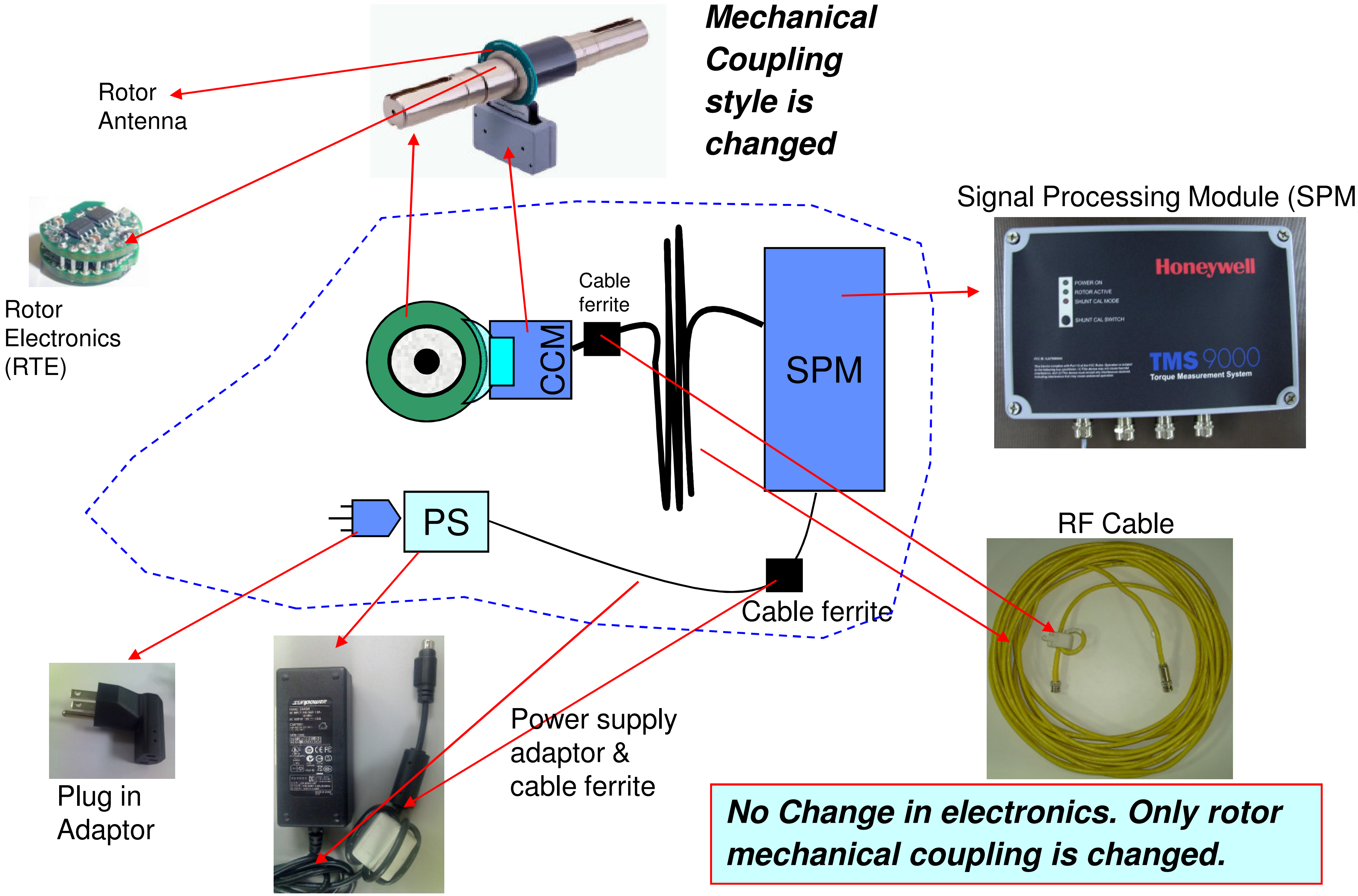
Mechanical Coupling style is changed



No Change in electronics. Only rotor mechanical coupling is changed.

TMS9000 Gen II Connection diagram

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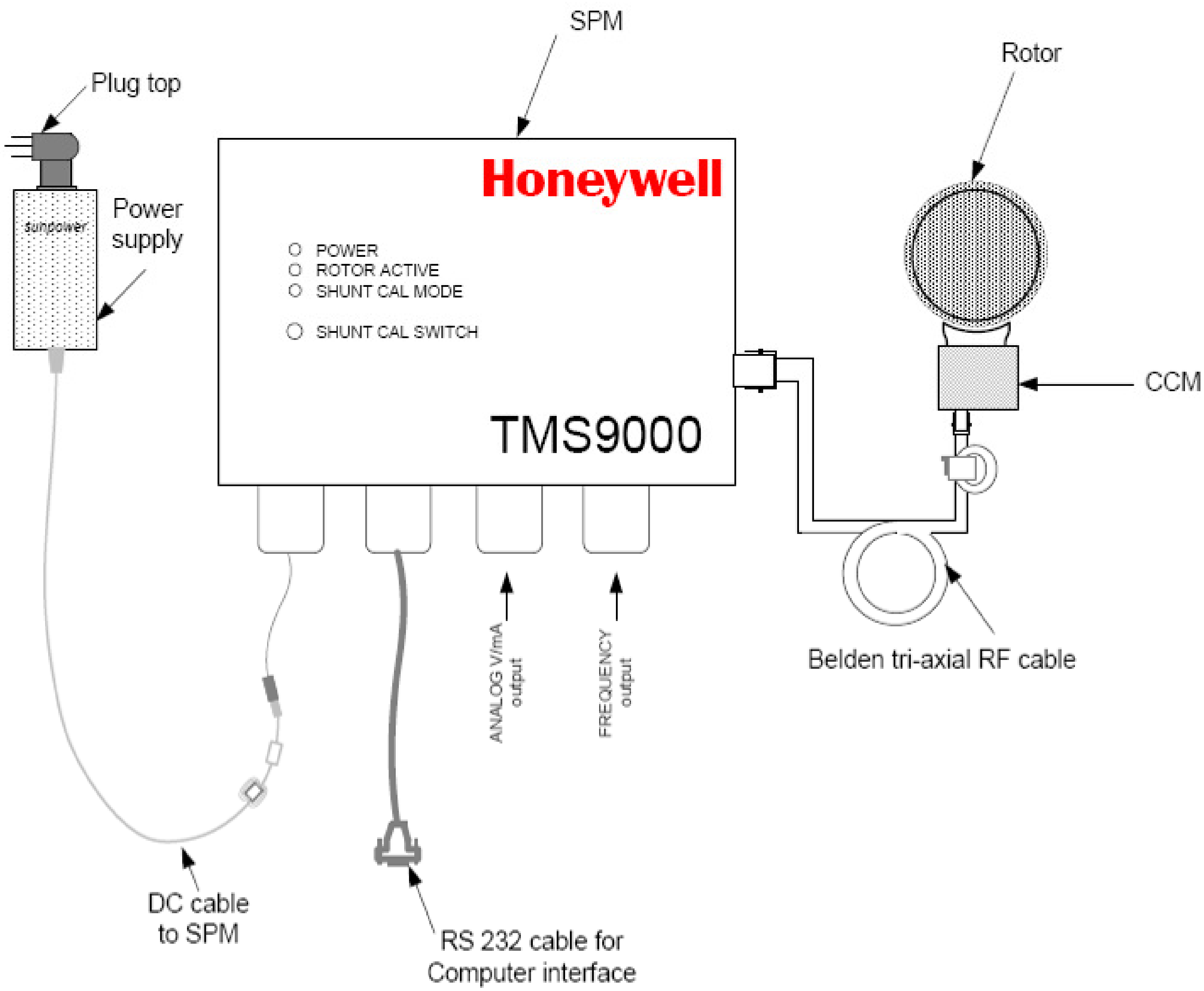

Radiated emission test summary: 1MHz-30MHz

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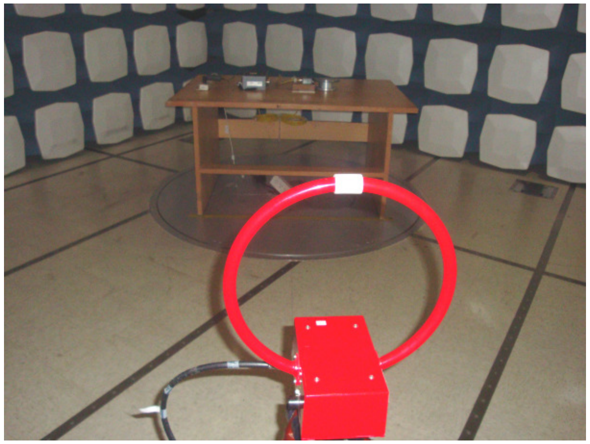
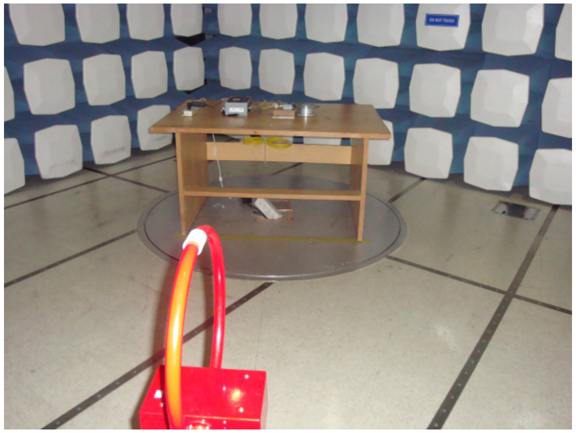
Test Setup photos:





Limits:

Name of test	Basic Standard	Specification
Radiated Emission Test	FCC Part 15.209	Quasi peak Limits (at 3m Distance): 1 MHz to 30 MHz : 69.52 dBuV/m
Radiated Emission Test	FCC Part 15.225	Quasi peak Limits (at 3m Distance): 13.553 MHz to 13.567 MHz : 123.99 dBuV/m

Summary:

	Radiated Emission (1 to 30MHz) measured using loop antenna peak readings in dB uV/m			
	perpendicular		parallel	
	13.56MHz	27MHz	13.56MHz	27MHz
DIN 65	71.949	49.256	71.188	48.907
DIN 90	74.221	52.988	72.372	51.374
DIN 120	78.045	52.517	74.357	50.863
DIN 150	79.672	53.444	75.24	52.055
DIN 180	81.421	55.95	76.235	54.494
DIN 225	82.11	54.238	76.843	54.074

DIN225 (largest Rotor & CCM Antenna) is the worst case model

Loop Antenna Scans DIN65, 90 & 120

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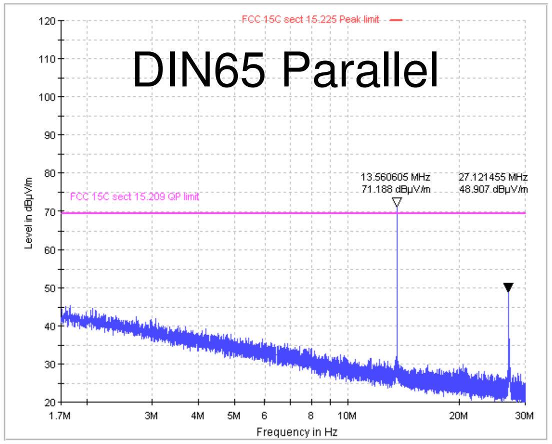
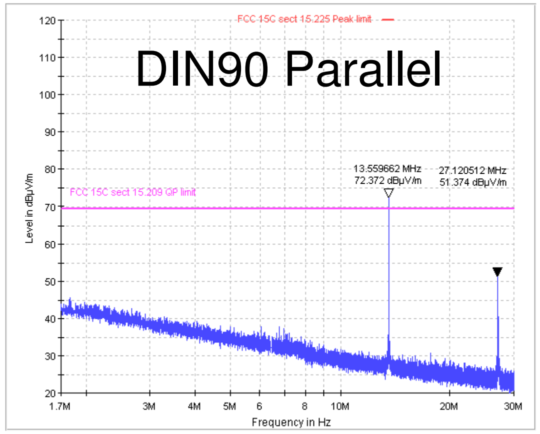
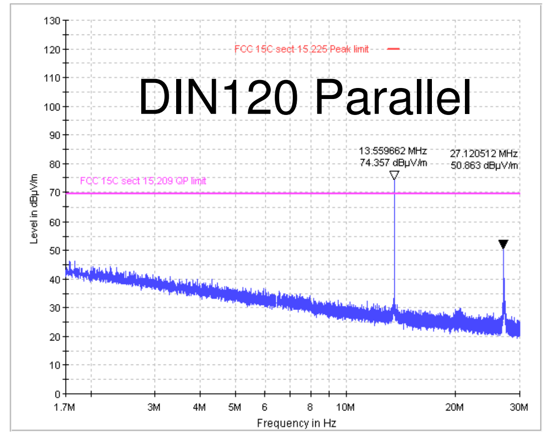
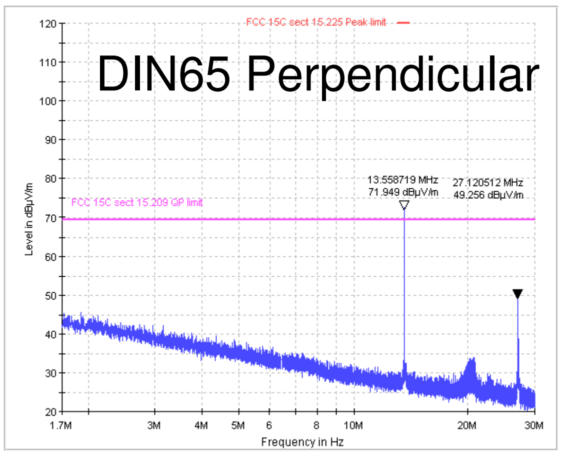
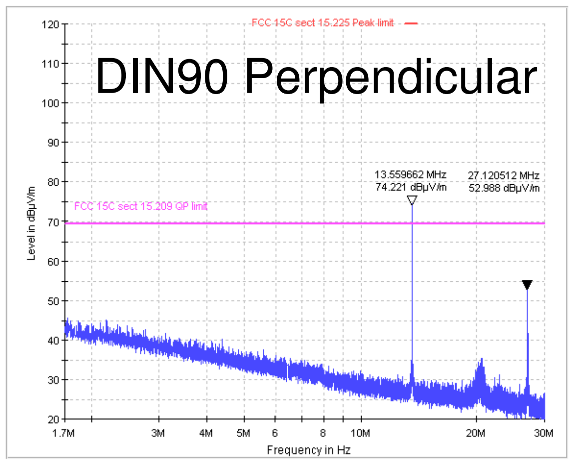
(Parallel & Perpendicular polarization of Antenna)

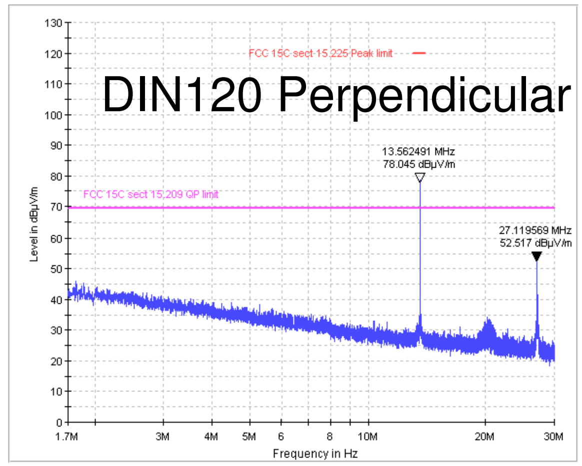












As the size of Rotor increases, the Radiated emissions also increase

Loop Antenna Scans DIN150, 180 & 225

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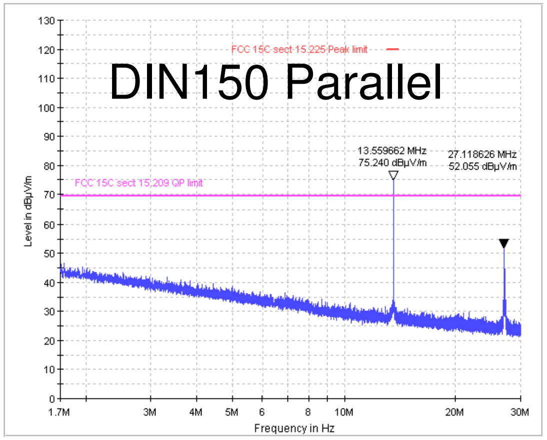
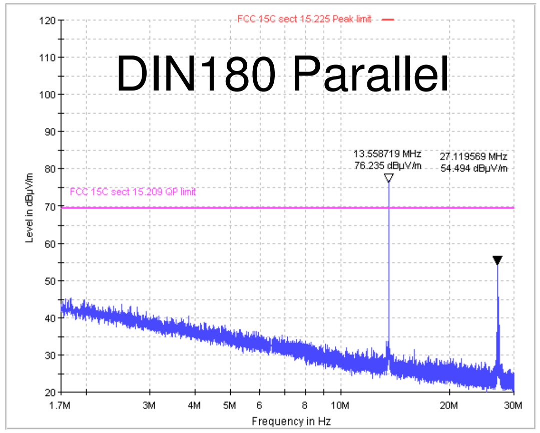
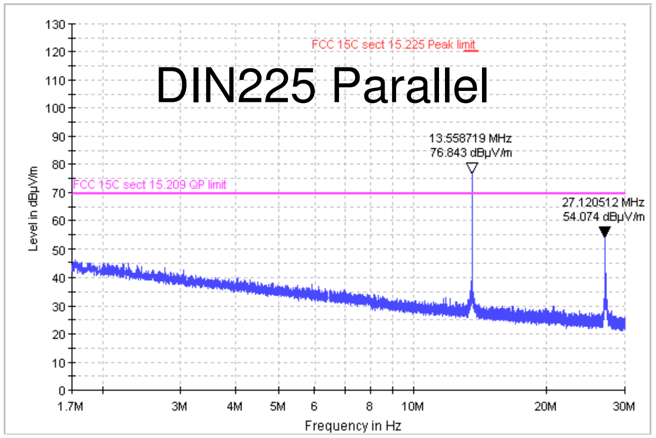
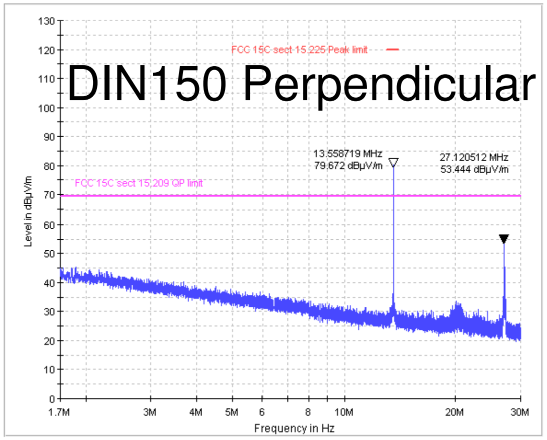
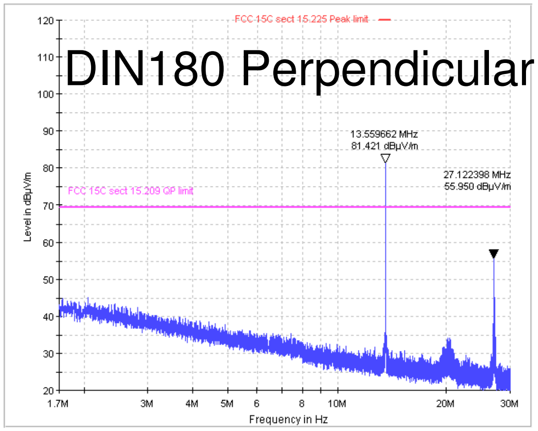
(Parallel & Perpendicular polarization of Antenna)

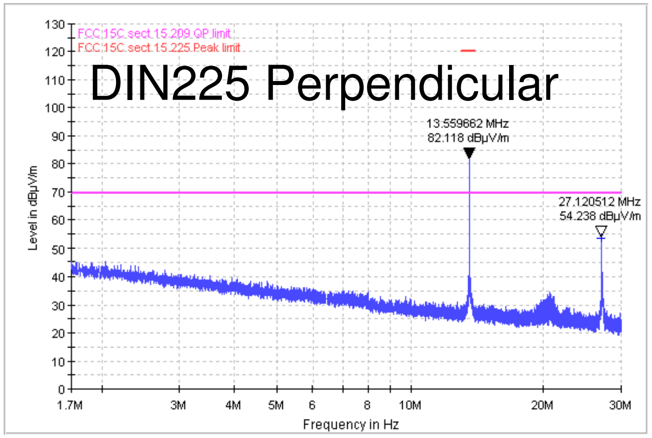












As the size of Rotor increases, the radiated emissions also increase. DIN225 has the largest size of Rotor and CCM. So, it is the worst case model for Radiated Emissions

Radiated emission: 30MHz-1GHz

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Limits:

Name of test	Basic Standard	Specification
Radiated Emission Test	FCC Part 15.209	Quasi-peak Limits (at 3m Distance): 30 MHZ to 88 MHZ : 40 dBuV/m 88 MHZ to 216 MHz : 43.5 dBuV/m 216 MHz to 960 MHz : 46 dBuV/m 960 MHz to 1 GHz : 54 dBuV/m

Test Setup photos:

Radiated emission 30MHz-1000MHz scans

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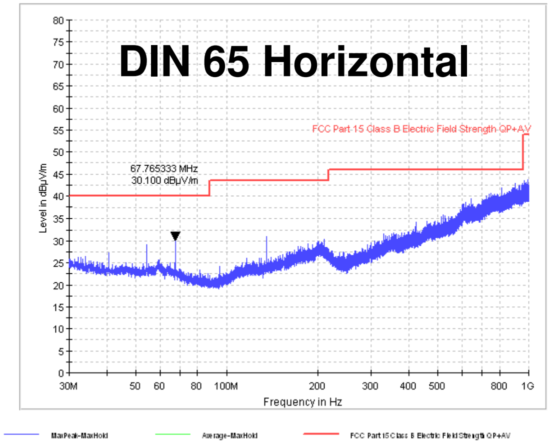
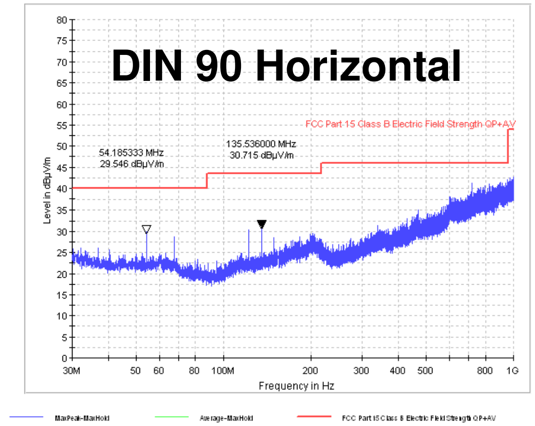
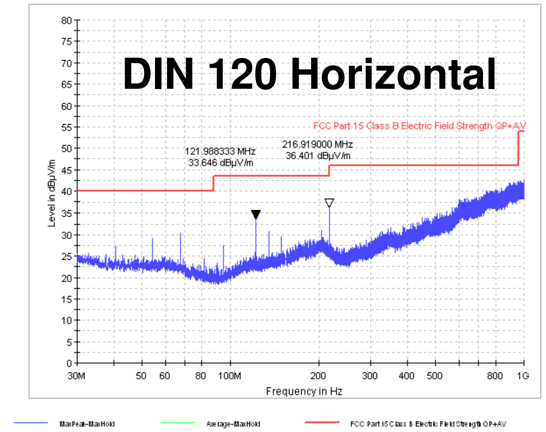
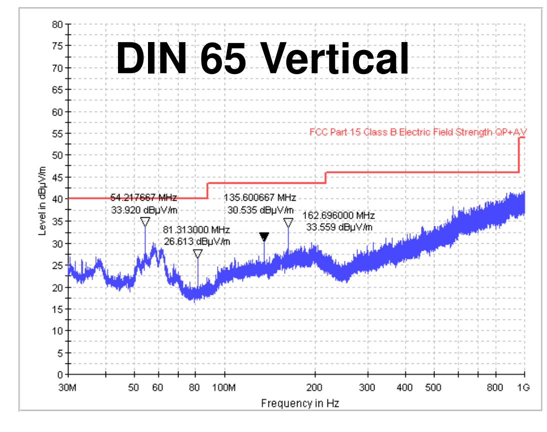
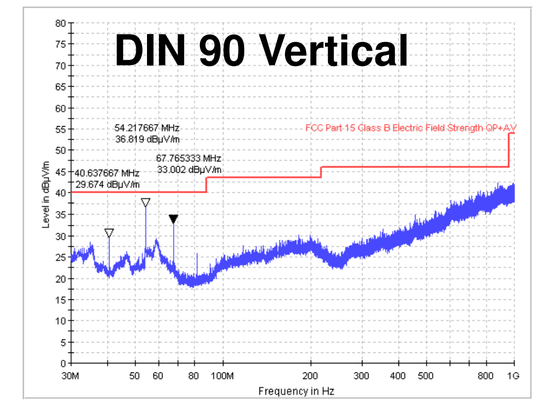
Horizontal & Vertical Polarization:

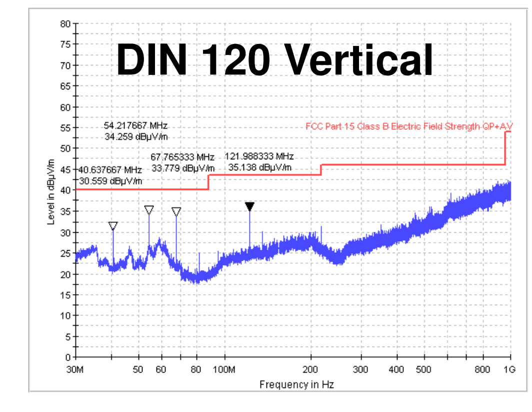












Note: The readings in the above charts are peak measurements. Quasi-peak measurement will be lower.

As the size of Rotor increases, the radiated emissions also increase

Radiated emission 30MHz-1000MHz Vertical scan

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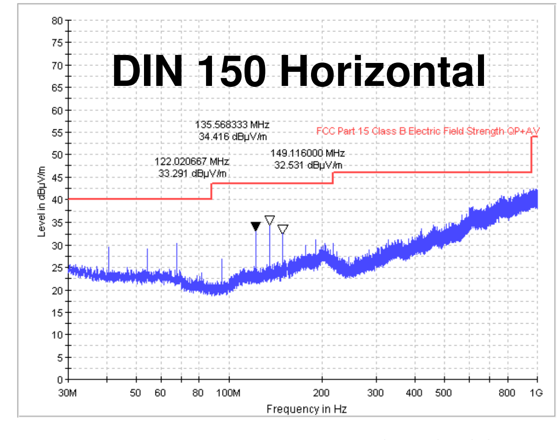

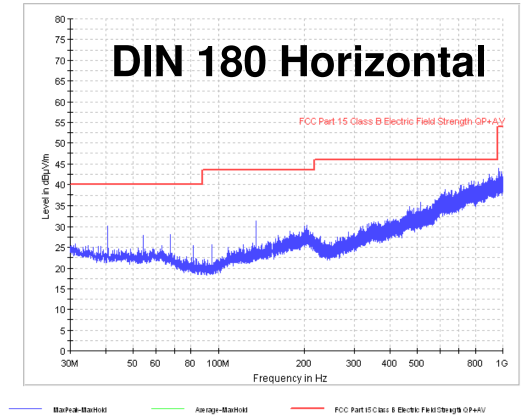

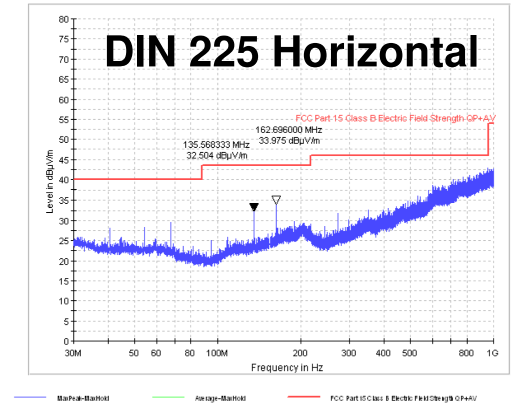

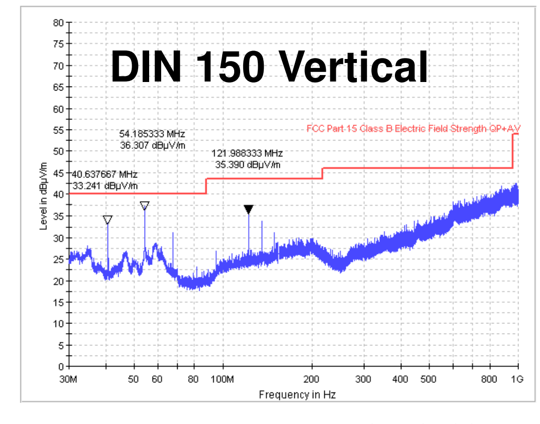

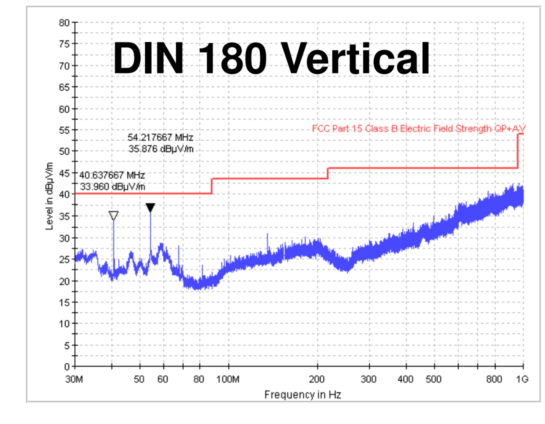

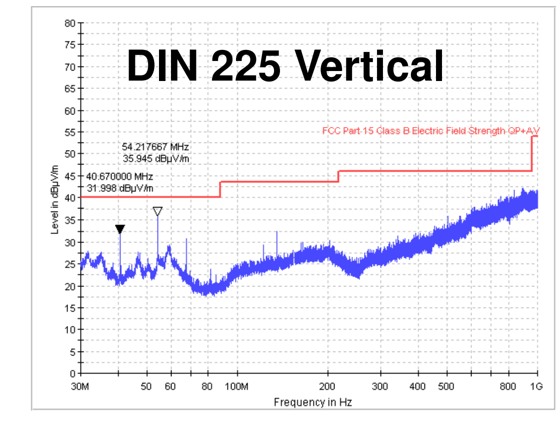

Note: The readings in the above charts are peak measurements. Quasi-peak measurement will be lower.

As the size of Rotor increases, the radiated emissions also increase. DIN225 has the largest size of Rotor and CCM. So, it is the worst case model for Radiated Emissions

Conducted emission 150KHz to 30MHz

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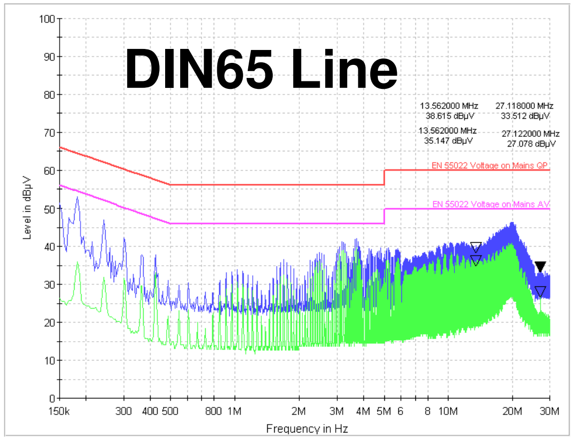
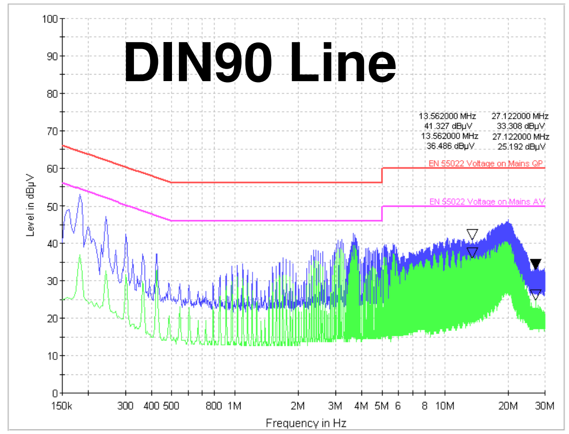
Limits:

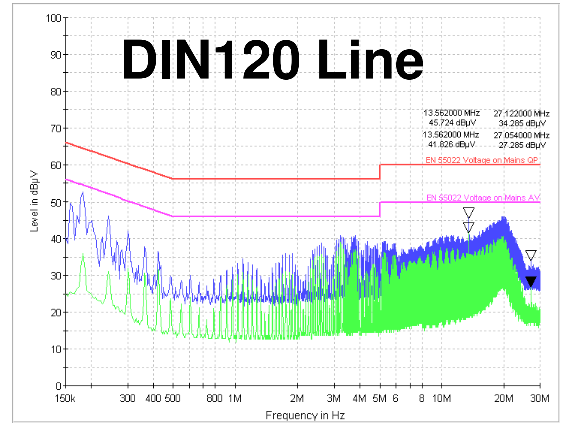
Name of the Test	Basic Standard	AC/DC/ Signal Port	Specification
Conducted Emission Test	FCC part-15.207	110V/ 60Hz Power Port	<u>**Quasipeak Limit**</u> **150kHz -500kHz :** 66 – 56 dBµV **500kHz -5MHz :** 56 – 60 dBµV **5MHz-30MHz :** 60 dBµV <u>**Average limit**</u> **150kHz -500kHz :** 59 – 46 dBµV **500kHz -5MHz :** 46 – 50 dBµV **5MHz-30MHz :** 50 dBµV

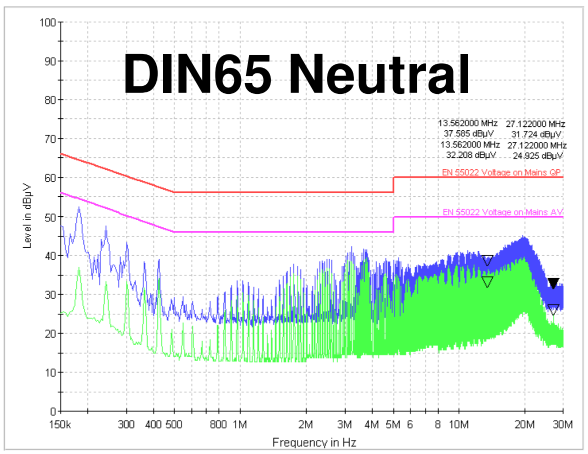
Test Setup photos:

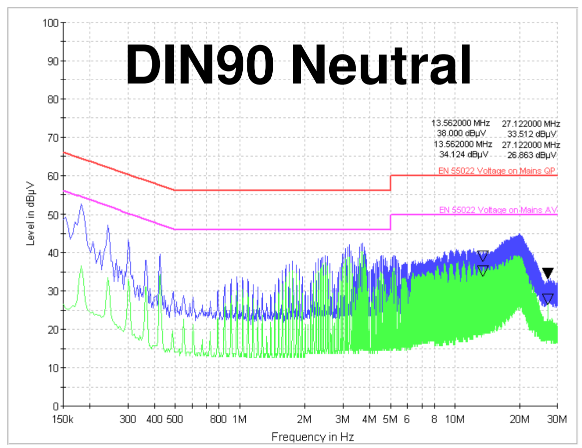
Conducted emission scans

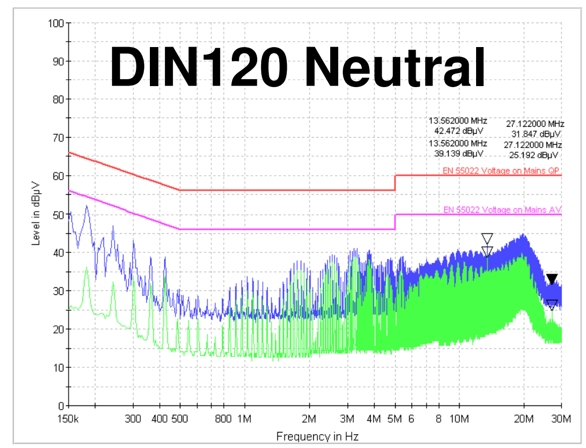












Note: The readings in the above charts are measurements made using 110V AC supply

As the size of Rotor increases, the conducted emissions also increase

Conducted emission scans

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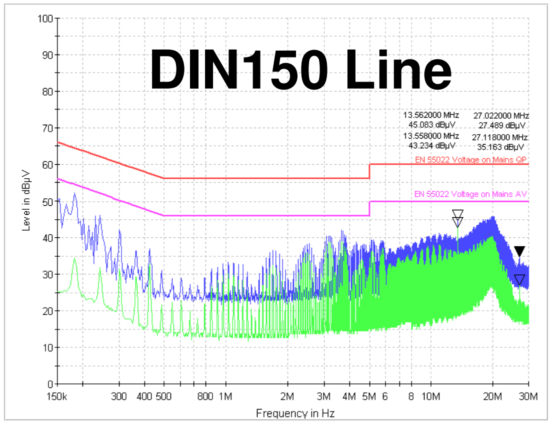

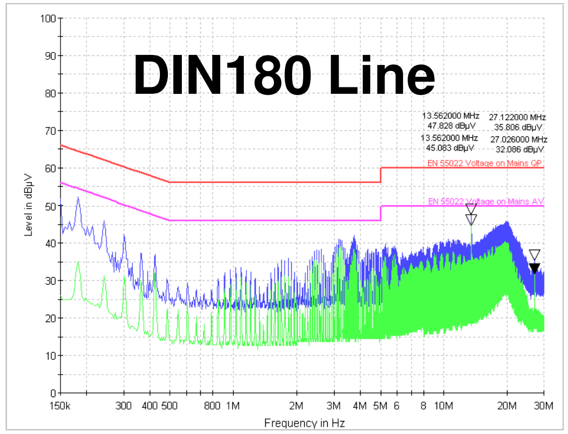

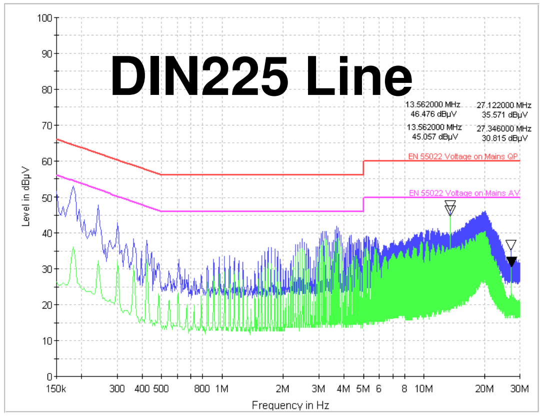

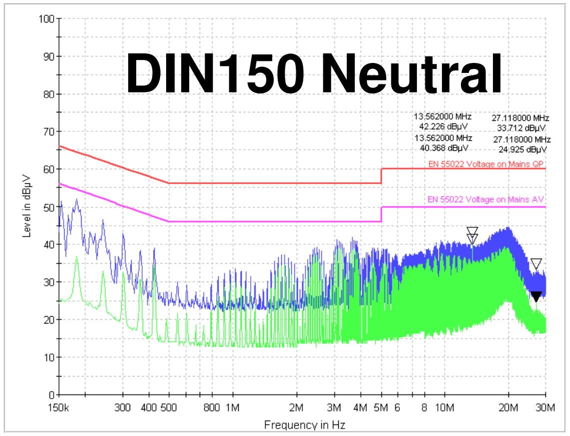

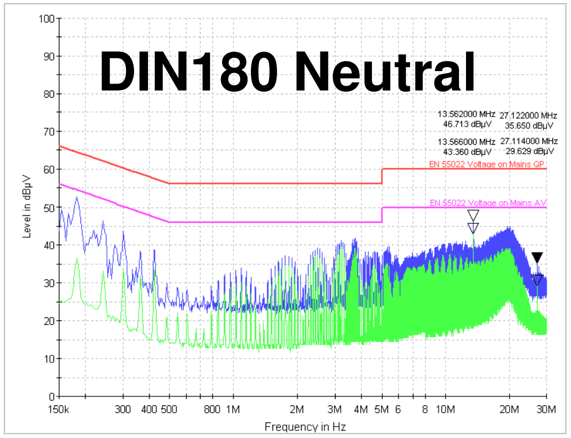

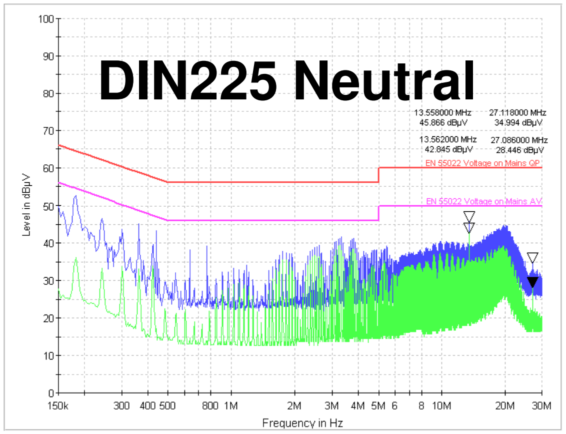

Note: The readings in the above charts are measurements made using 110V AC supply

As the size of Rotor increases, the conducted emissions also increase. DIN225 has the largest size of Rotor and CCM. So, it is the worst case model for Conducted Emissions

Conclusions:

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- As the size of Rotor increases, the emissions also increase.
- 225 has the largest size of Rotor and CCM. So, it is the worst case model for emissions.
- The only difference between the three styles of coupling (flange to flange, Integral coupling and shaft to shaft) is the mechanical coupling. But the electronics is the same. So, this can be considered as a Class 1 permissive change.

Analysis of Rotary Antenna Emissions- Theoretical Approach to identify worst case model

Geometry of the rotary antenna

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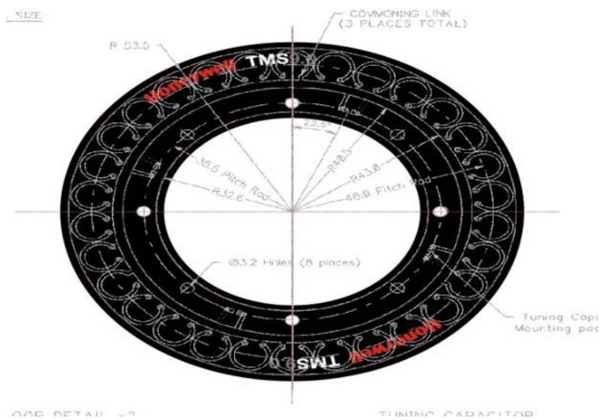
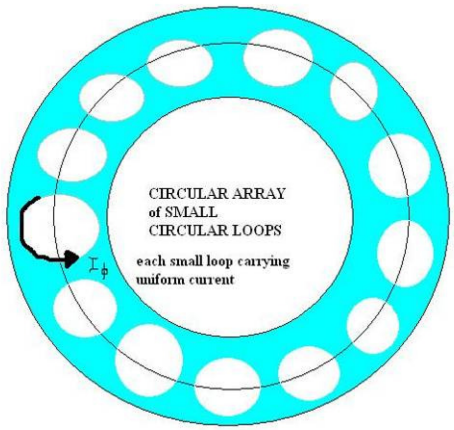
Actual geometry of the Rotary Antenna



An approximate model for Electromagnetic Analysis



Field of a small circular loop [ref:1]

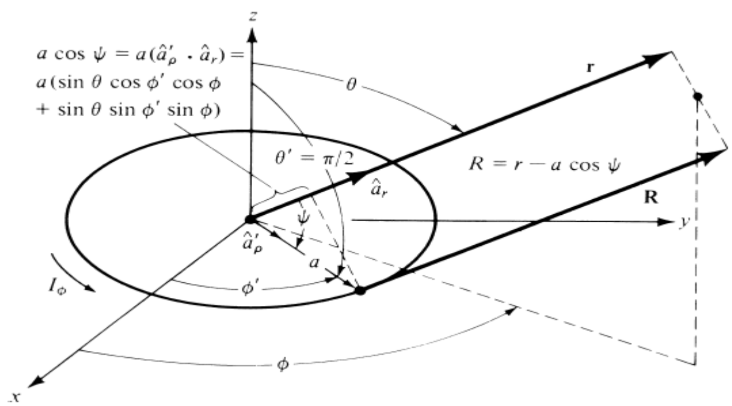


Figure 5.2 Geometrical arrangement for loop antenna analysis.

$$H_r = j\frac{ka^2 I_0 \cos\theta}{2r^2}\left[1 + \frac{1}{jkr}\right]e^{-jkr}$$

$$H_\theta = -\frac{(ka)^2 I_0 \sin\theta}{4r}\left[1 + \frac{1}{jkr} - \frac{1}{(kr)^2}\right]e^{-jkr}$$

$$H_\phi = 0$$

$$E_r = E_\theta = 0$$

$$E_\phi = \eta\frac{(ka)^2 I_0 \sin\theta}{4r}\left[1 + \frac{1}{jkr}\right]e^{-jkr}$$

$$\left.\begin{aligned} H_r &\simeq \frac{a^2 I_0 e^{-jkr}}{2r^3}\cos\theta \\ H_\theta &\simeq \frac{a^2 I_0 e^{-jkr}}{4r^3}\sin\theta \\ H_\phi &= E_r = E_\theta = 0 \\ E_\phi &\simeq -j\frac{a^2 k I_0 e^{-jkr}}{4r^2}\sin\theta \end{aligned}\right\} kr \ll 1$$

This Slide shows the Electromagnetic Field due to a small circular loop.

The right hand side expressions shows the E-field and H-Fields of the small circular loop

The centre-bottom shows approximate Near-field expression for a small circular loop with uniform current when kr<<1, r being the observation point distance.

The fields of the entire circular array of small loops [ref 2]

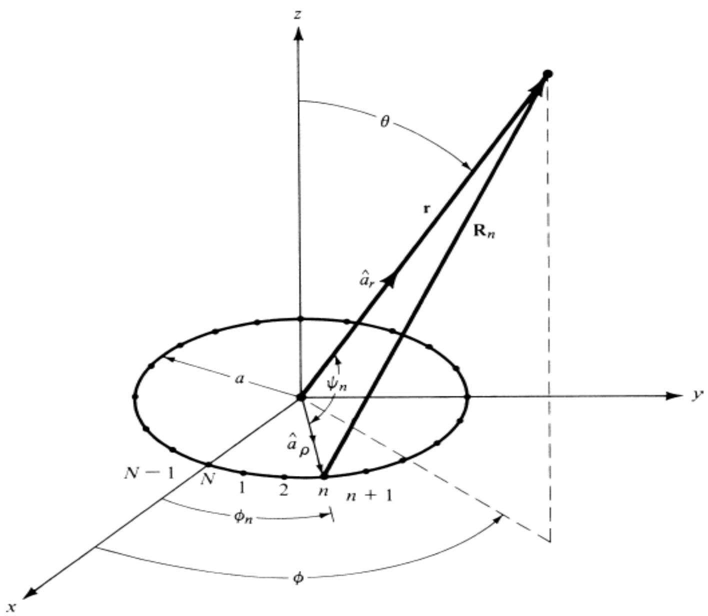


Figure 6.37 Geometry of an N-element circular array.

$$E\emptyset = \frac{Zo(Ka)^2}{4r} sin\theta\{1 + \frac{1}{jKr}\}\, e^{-jkr}[A.F]$$

Where A.F is the array factor that distorts and amplifies the resultant pattern

$$\mathrm{AF}(\theta, \phi) = \sum_{n=1}^{N} I_n e^{j[ka \sin\theta \cos(\phi - \phi_n) + \alpha_n]}$$

This slide shows the resultant E-field due to all the small circular loops arranged as a circular radiating array.

The figure shows a circular array of isotropic (point sources) radiators.

The resultant field expression shown on the right is a product of element pattern function(small circular loop) and the Array Factor. The AF represents the superposition of radiating elements in an array and depends on the magnitude and phase of the excitation current of each radiating element.

Near Field Emission approximate expressions

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At the Near field of small circular Loop,

$$E_r = E_\theta = 0$$

$$E_\phi = \frac{-j\eta\, a^2 k\, I_o\, e^{-jkr}}{4r^2} \sin\theta$$

Therefore the peak value (ignoring the sine term) $\Rightarrow E = \dfrac{-j\eta\, a^2 k\, I_o\, e^{-jkr}}{4r^2}$

Approximating the above expression,

$$\boxed{E = \frac{Z_o\, I S}{2\lambda D^2}}$$

where $S = \pi a^2$ Area of loop

$k = \dfrac{2\pi}{\lambda}$

$r = D$

Similarly for the Magnetic field,

$$H_\phi = 0$$

$$H_r = \frac{a^2 I_o\, e^{-jkr}}{2r^3} \cos\theta \; ; \quad H_\theta = \frac{a^2 I_o\, e^{-jkr}}{4r^3} \sin\theta$$

Therefore the peak value $\Rightarrow \boxed{H\ (A/m) = \dfrac{I S}{4\pi D^3}}$

and the Near field wave is still coupled with the circuit,

Therefore the impedance $\boxed{Z_{wave} = \dfrac{E}{H} = \dfrac{Z_o\, 2\pi D}{\lambda}}$

valid for $D < 48/f$ (MHz)

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Summary & Conclusion:

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- It is observed that the near-field is magnetic in nature.(generated by a circuit carrying high current and low voltage)

- The radiated field expressions, obtained by solving the magnetic vector potential of the small circular loops correlate with the general approximate near-field expressions of a EUT which is mostly magnetic in nature.

- The Field strength is Directly proportional to the current in the loops (Io).

- The field strength is directly proportional to the Area of the Loops(A).

- The field strength is directly proportional to the Number of Loops(N).

- The induced interference is also dependent on frequency. The effects induced into a second circuit are proportional to how fast the field changes (i.e., proportional to the time derivative of the field).(f)

- High-frequency signals and signals with rapid rise times do not create larger energy in the near field, but they do cause larger induced currents and voltages in any nearby circuits.

Hence one may conclude that the rotary antenna of the largest diameter, larger no of loops(coils) and larger loop area, has the maximum emissions.

References

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