Tutorial SC RF 2019

What is the value for surface resistance of copper at room temperature and 1 Ghz

A) 8 milli Ohm
B) 17 milli Ohm
C) 20 nano Ohm

What is the resistance of a copper wire of 1 meter length and 1 square millimetre cross section

A) 1 Ohm
B) 1 milli Ohm
C) 17 milli Ohm

What is the resistance of a copper block (cubus) with the length of each side=1 meter assuming that you measure across opposite sides and also assuming perfectly conducting contact metallisation on those side where you measure (not on the others, why?)

A) 17 nano Ohm
B) 17 Kilo Ohm
C) 1 micro Ohm

How does the surface impedance of copper scale with frequency

A) Increases proportional to frequency
B) Decrease proportional to frequency
C) Increases proportional to SQRT (frequency)

When cooling down copper to cryo temperatures we profit from the RRR. What is the meaning of this abbreviation?

A) Residual resistance ratio
B) Right range rule
C) Red roughness rubble

In the LHC beam screen we have a thin (50..75 micron) copper layer inside the beam screen (stainless steel, why) with rather pure cooper despite (why?) the collamination process and a RRR value of 100 at 20 K of 100. Neglecting magnetoresistance what is the impact on the surface impedance of the beamscreen above 1 MHz (why above 1 MHz?)

A) Reduction by a factor 10 compared to ambient
B) Increase by a factor 100 compared to ambient
C) No change

What is the numerical value of the residual surface resistance for a 3 Ghz high purity niobium cavity at very low temperature (hint: read from a slide in the lecture)

A) 4 nano Ohm
B) 32 nano Ohm
C) Zero

How does the surface impedance of a superconductor scale with frequency f?

A) Linear
B) Proportional Square root (f)
C) Proportional f^2

When doing RF surface impedance measurements on superconductors you should avoid Ohmic contacts (like the 4 wire probe [what is this]); why?

A) The unavoidable contact resistance would spoil your measurement
B) Too much heat loss via those contact probes
C) Thermo-electric potentials would impact your RF measurement

A superconducting cavity at 1 GHz has an unloaded Q of 10E10. In order to measure it you must do some coupling to an instrument and you decide to go for critical coupling in an S11 measurement.

A) Determine the loaded Q and also the external Q in this case (see Rf lecture)
B) What is the time constant for this cavity (1/e decay of the field)
C) Sketch a possible measurement setup and discuss advantages and disadvantages of your suggestion
D) Why are superconducting cavities usually not operated at critical coupling?
E) Assume that your cavity has an R/Q of 50 Ohm and a loaded Q of 2E 10. Your "home" made "high power network-analyser" (provide a sketch off hand) can provide up to 10 Watt input power.
F) You are operating this device in a cryo test stand. What is the maximum electron energy that can be produced there (electron are always around in such a cavity e.g. from cosmic muons); possible consequences (radiation protection)?
G) Dissipating 10 Watt at say 2 deg K would require much more power for your cryo compressor on the surface? Give a reasonable estimate (ballpark).

A) With an unloaded Q_0 of 1E11 and critical coupling we get a loaded Q_L of 5E10

B) With the formula: $Q_L = \pi \, \Delta T \, f_0$ we obtain $\Delta T = \tau = Q_L / (\pi f_0) = 100/\pi = 31.8$ seconds

C) Sketch a PLL circuit similar to slide number 64 in the SC RF lecture or use a simple oscillator circuit i.e. a cavity as transmission resonator with weak coupling on both sides (to get nearly unloaded Q) but not more than 30 dB transmission loss at resonance.

D) The very long filling (and of course decay) time is not compatible with normal beam loading requirements where the cavity but be at the correct power level when the next bunch or batch arrives. Also the resonance frequency is likely to be unstable due to boiling helium noise and the impact of radiation pressure (Lorenz forces)

E) Such a cavity is normally in a cryostat AND in a radiation bunker thus lets assume as length for the connecting cables to the “control room”a reasonable number e.g. 30 meter.If you would like to deliver 10 Watt into the cavity and assume 6 dB one way attenuation of your cable (at 1 Ghz) + some additional losses from your directional couplers rather close to the cavity your power amplifier should be able to deliver 50 Watt. The you need either a bidirectional coupler with say 20 db coupling and good directivity to separate the replica of the forward and backward going wave and after some reference measurements (a kind of calibration) you would have a reasonable high power VNA when using the output signal of your directional couplers with the a normal VNA in the control room.

F) With the number given above the cavity would have an impedance of (R/Q)Q= 2E10 50 =1E12 =1Tera Ohm. 10 Watt on 1 TOhm produce 3.16 Mega Volt…very hard X-rays. Ionizing radiation protection !

G) The typical “penalty factor is about 300..500..thus for 10 Watt at cryo you should foresee 5 KW on the surface but there maybe also transmission line heat leaks thus better go for a 10 KW compressor.