ADJUSTABLE HIGH POWER COAX COUPLER WITHOUT MOVING PARTS*

M. Neubauer, A. Dudas, R. Sah, Muons, Inc. Batavia, IL 60510, U.S.A.
A. Nassiri, ANL, Argonne, IL 60439, U.S.A.

Abstract

An RF power coupler is designed to operate without moving parts. This new concept for an adjustable coupler is applicable to operation at any radiofrequency. CW operation of such a coupler is especially challenging at lower frequencies. The basic component of the coupler is a ferrite tuner. The RF coupler has no movable parts and relies on a ferrite tuner assembly, coax TEE, and double windows to provide a VSWR of better than 1.05:1 and a bandwidth of at least 8 MHz at 1.15:1. The ferrite tuner assembly on the stub end of the coax TEE uses an applied DC magnetic field to change the Qext and the RF coupling coefficient, β, between the RF input and the cavity. Recent work in making measurements of the loss in the ferrite and likely thermal dissipation required for 100 kW CW operation is presented.

INTRODUCTION

Previous design details were presented last year at IPAC10[1]. The variable coupler is composed of three fundamental elements:

1. A variable ferrite or garnet tuner.
2. Double coax windows, λg/4 center to center.
3. EIA 6-1/8 Standard Coax Tee and components.

Muons, Inc. was awarded a Phase II to complete the double window coax and is currently working on the completion of that design. Some of the elements of that work will be presented.

Work on the ferrite tuner has progressed since the last paper was presented and forms the major portion of this paper.

FERRITE TUNER

Ferrite tuners are not a new concept. They all make use of the principle that a biasing magnetic field is applied to the ferrites orthogonal to the rf fields and as a result the permeability of the ferrites can be varied by changing this biasing magnetic field: Of these designs only one tuner has the ferrites totally immersed in the water. In the rest of the designs, the heat is dissipated through the walls, and a cooling jacket surrounds the tuner[2].

The tuner in the design discussed here is a coaxial cavity with NiZn ferrite or yttrium garnet disks surrounded by a liquid dielectric. This dielectric removes the heat in a closed system with a heat exchanger, as describe in Dr. Popovic's invention [3]. This section of coax is surrounded by a solenoid to provide the magnetic field orthogonal to the TEM fields in the coax. The change in magnetic field changes the characteristics of the cavity, the Qext, and therefore the β of the system. Experimental results from a test fixture designed to measure the magnetic fields required and the losses expected for representative materials are discussed below.

Test Fixture

The test fixture is designed based upon the work of G. Bush [4]. It is shown in Fig. 1.

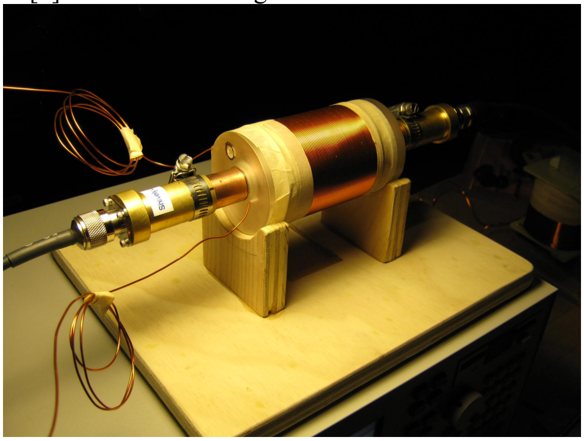

Figure 1: Coaxial test fixture with solenoid field.

The test fixture is built in EIA 7/8 coax. This scaled down version of the coax allows for collecting experimental data on a variety of ferrites in order to determine the optimum for the final design. The optimum will be a ferrite whose loss is lowest at the frequencies of operation.

The components of the fixture are shown in Fig 2.

Figure 2: Solenoid test fixture, with ferrite on the center conductor of a 7 inch long coax.

Two different size ferrites are being tested (.25 inch long and 1.00 inch long), and the data from the S11 and

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#mike@muonsinc.com

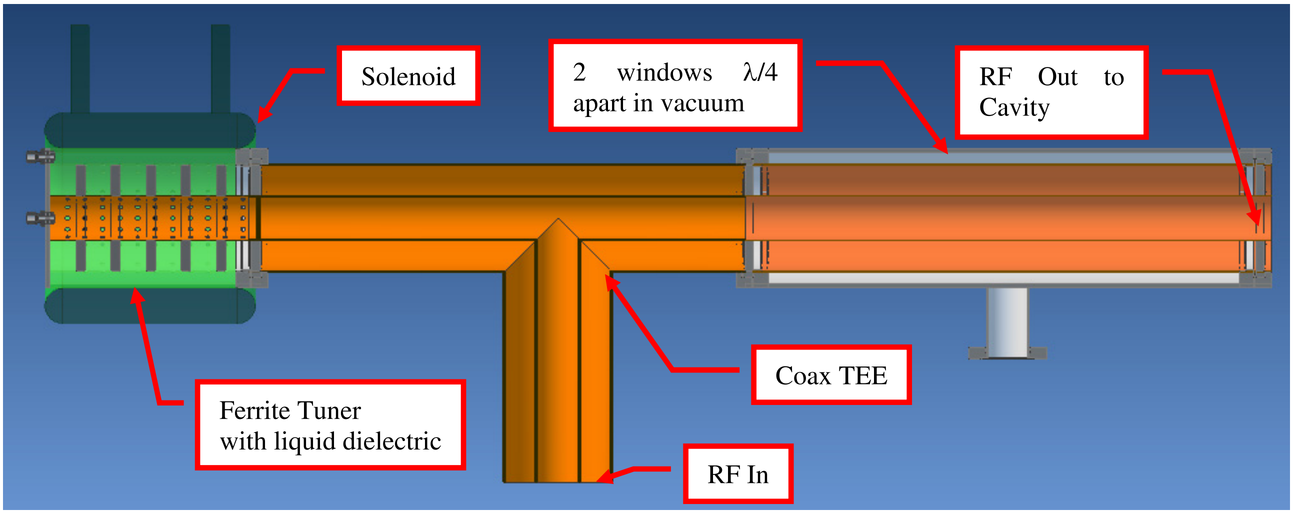

Figure 3: Cutaway view of the proposed RF coupler. Total length is 70 inches for 100 MHz. The coax is standard EIA 6-1/8 inch.

S21 is being analyzed to determine the complex permeability and dielectric based upon the prior work done by W. Hartung[5]. The materials currently in the test plan are shown in Table 1.

Table 1: Materials Chosen to be Analyzed in the Test Fixture.

Material	Model/part no.	Saturation Magnetization [4pMs]	Supplier
NiZn	N40	2500	CMI
NiZn	CM48	4400	CMI
Similar to: $Y_3Al_{0.66}Fe_{4.34}O_{12}$	G-810	800±5%	Trans-Tech
YIG	G-113	1780±5%	Trans-Tech
Nickel Spine1	TT2-111	5000±10%	Trans-tech
Yttrium (narrow line width)	YG-1780	1780	NMG
Aluminum Doped	AL-1200	1200	NMG
Magnesium Ferrites	MF-3000	3000	NMG

The object is to find materials that are lowest in insertion loss and allow for changes in permeability. This work continues and some preliminary results are presented.

Figure 4 shows the change in permeability for a change in the solenoid field of 0 to 420 gauss around the coax line. It increases at the low frequencies and decreases at the higher frequencies. In Figure 5 the change in the loss tangent of the permeability is shown. At the lowest frequencies, the change in the real part is three times that of the loss tangent which hardly changes at all. This is good, but it is even better at the higher frequencies where the loss tangent decreases by 50% while the real part of the permeability changes 5%. The other materials will be tested as we determine the optimum material for the application in the design of a variable RF coupler without moving parts.

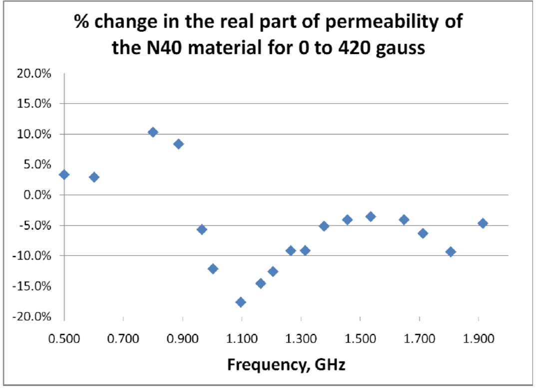

Figure 4: Measured results for real part of permeability in N40 material.

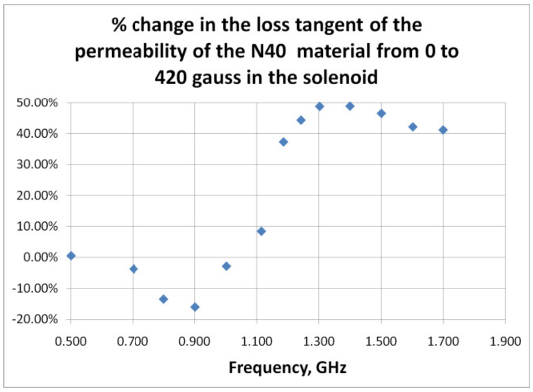

Figure 5: Measured change in loss tangent for the permeability for N40 material.

At 500 MHz, the loss of the one inch long sample of N40 material was 2.68 db as measured by S21. With 420 gauss in the solenoid magnet, the loss decreased by 3.5%. However, in a significant finding, with a transverse field magnet (transverse to the axis of the coax), the loss at 500 MHz was reduced to .38 db with 1400 gauss! So for this particular material in a coax with TEM waves, the most effective field was not solenoidal, but transverse.

If this assembly is scaled up for operating at 100 kW CW into a short (the RF goes through the ferrite twice: forward and reflected), then the total loss in the N40 ferrite would be reduced from 35.5 kW to 8.3 kW, by the use of a transverse field rather than a solenoidal field.

This finding is surprising and requires further investigation.

DOUBLE COAX WINDOW

Muons, Inc. has a Phase II program to develop a double coax window assembly. The first coax window built with a compression seal about the outside is shown in Fig 6.

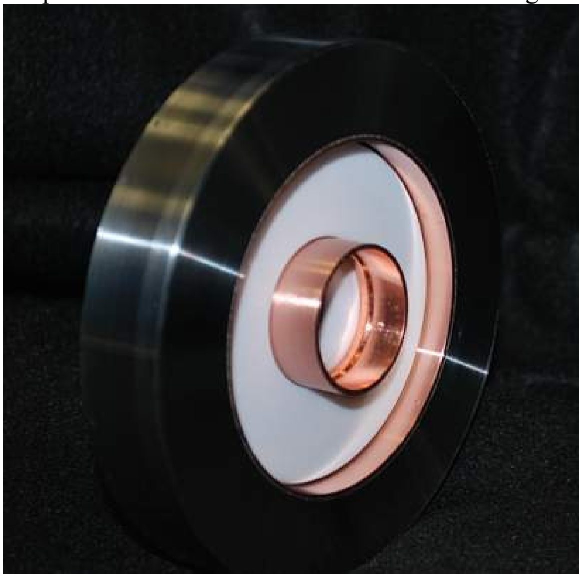

Figure 6: Coax window brazed with a compression ring.

Table 2: Comsol Calculations of power dissipated and the maximum gradient in the EIA 3-1/8 coax line with alumina windows (at room temperature) with tanδ=.0001 at 100kW input power [6].

Frequency [MHz]	**Watts in a window at 100 kW pin**	**Gradient at 100 kW [V/m]**
1300	18.6	2.29e+05
805	12.2	2.56e+05
650	10.7	2.72e+05
325	5.14	3.77e+05

In the adjustable high power coax coupler without moving parts, the match through the double windows is dependent upon the spacing between them and the operating frequency of the coupler.

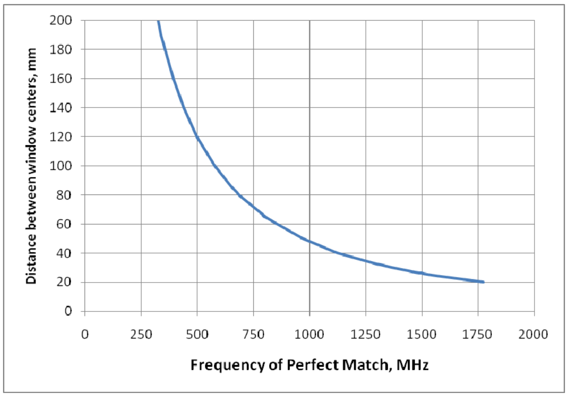

Figure 7: Two alumina windows 7.6 mm thick modelled in EIA 3-1/8 coax for the distance between them which creates a near perfect match[6].

CONCLUSIONS

The investigation of the ferrites that might be used in the tuner portion of this coupler has produced surprising results for the desired orientation of the magnetic field for a TEM wavein a coax. Transverse fields (transverse to the axis of the coax line) have a much greater impact on the losses than previously reported. Further work will be done to understand this phenomenon if a Phase I project is approved.

ACKNOWLEDGEMENTS

The progress on the double window assembly has been slow due to the untimely death of one of our friends and valuable collaborators at JLAB, Tom Elliot. Tom made valuable contributions to a wide variety of projects, not the least of which was the brazed assembly of the window shown in Fig. 6. He will be missed.

REFERENCES

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