6-10-97

THE UNIVERSITY OF MICHIGAN
DIVISION OF RESEARCH DEVELOPMENT AND ADMINISTRATION

3003 South State Street
Ann Arbor, MI 48109-1274

June 10, 1999

Dr. Richard Bradley
National Radio Astronomy Observatory
2015 Ivy Road
Charlottesville, VA 22903

Dear Dr. Bradley:

On behalf of Professor J. R. East and the University of Michigan we are submitting a statement of work and budget for consideration.

If we can provide any additional information please contact our office at 734 764-7237.

Sincerely,

David M. Plawchan
Senior Project Representative

DMP:ml

Statement of Work

The goal of the research in this proposal is to develop techniques to fabricate low cost multiplier chains for NRAO radio telescope array applications. The final array will require a large number of multipliers operating in the frequency range between W band and one terahertz. The specifications require modest efficiencies but very wide bandwidths. Low Q, Finite Ground Coplanar (FGC) line structure multipliers developed under earlier research at The University of Michigan are ideal for this application. These multipliers have a measured bandwidth greater than 10 GHz in W band and efficiencies of 17% from planar probe input to planar probe output. They are fabricated using an MMIC technology that can be extended to batch fabrication of large numbers of similar structures.

We plan to develop waveguide based planar multipliers to match sources #1 and #2 in the suggested MMA LO plan. These sources closely match existing designs and will require little new test equipment. We plan to

1. Optimize existing multiplier designs to match desired output frequency ranges, 65-85 GHz for source #1 and 72-95 Ghz for source #2,
2. Modify designs to include folded stubs for integration into waveguide blocks,
3. Optimize waveguide transition designs for proper frequencies,
4. And using the designs realized in step 3, design Si micromachined versions of the probes for assembly with the multipliers.

By the end of the project we hope to have designs for waveguide multipliers that can be fabricated in modest quantities to meet NRAO applications.

A budget is also attached. The one year budget is $29,965. It includes the cost of a graduate student research assistant for one term, plus tuition and lab fees. I plan to split the student's time between this project and another one, so the effort will be over an entire year. The lab fees cover the student's use of the Solid State Electronics Laboratory. This includes all the chemicals, mask making and use of all the processing equipment. There are other costs for particular pieces of equipment within the lab, but I don't expect to use them. The supplies item is $2000 for an MBE GaAs wafer for the multiplier fabrication. The is also a small amount of my time. Finally there is a 52% indirect cost on all the budget items except tuition.

At the end we plan to deliver to NRAO a technical report describing the project. This would include drawing of the final probe designs and mask layouts. We also hope to worked closely with NRAO to develop the facilities to fabricate these multipliers in the quantities needed for the MMA.

6/3/99

			BUDGET
J. East			
Project Director			
cal yr		5%	1,623
summer mos	0	0%	0
Grad Stu Res Asst		1	
Terms	1	50%	6,089
Subtotal			7,712
Fringe Benefits at		38%	2,931
Tuition			5,580
Materials and Supplies (Incl. postage, copies, toll)			2,000
Laboratory Fees			3,400
Subtotal			21,623
Indirect Cost		52.00%	8,342
Total			29,965

6-10-99

Subject: Re: MMA Multiplier Proposal
Date: Thu, 10 Jun 1999 16:07:15 -0400 (EDT)
From: "Jack R. East" <jeast@eecs.umich.edu>
To: Richard Bradley <rbradley@NRAO.EDU>

Richard,
You had some questions

(1) There are a couple of papers on the FGC lines and the multipliers. I attached a list. The main source of the details is in two thesis drafts. I don't have electronic versions,so I will get copies and send them down. I hope to get them tomorrow, otherwise I will be at MTT next week and will take care of it when I get home,

(2) I can't "promise" to deliver hardware under the rules of university contacts. However, I can give you any chips or complete bloocks that we get,

(3) Again, I need to think about doing large numbers of wafer runs. I will check up on the details and get back to you,

(4) I don't have problems with blocks at lower frequencies, but I do have problems with the W band size scale. I would like some help with that fabrication. What is the best way to get you the drawings? We typically give our machine shop autocad drawings.

(5) I would love to start thinking about the higher frequencies. One problem is our lack of measurement equipment above 120 GHz. I can get measurements at JPL, but it takes a lot of time. Do you have sources and other measurement equipment there? This is a real interesting project, so almost arrangement can work out. The more input and information exchange, the better.

I have a meeting in Washington July 7 & 8. Do you want to get together there and try to work out some details? My only worry is trying to do too many things at once with just one student.

Jack

On Thu, 10 Jun 1999, Richard Bradley wrote:

> *Dear Jack,*
> *>*
> *> Thanks again for the proposal. Overall I think it looks good, but I*
> *do have a few questions and comments for you:*
> *>*
> *1. Could you please send me a list of references to your previous work*
> *on the frequency multipliers.*
> *>*
> *2. As stated in your proposal, the "deliverable" to NRAO is a technical*
> *report including mask layouts and drawings. You also mention working*
> *with NRAO "to develop the facilities to fabricate these multipliers".*
> *The report is certainly needed but we would also like to have sample*
> *chips and perhaps complete multipliers for evaluation.*
> *>*
> *3. Once a particular multiplier design is proven suitable for the MMA,*
> *we would be interested in having your group fabricate all the chips*
> *necessary to equip the MMA with that multiplier (on the order of 150 or*
> *so chips). This would be under a separate contract at a later date.*
> *Are you interested in doing this work?*
> *>*
> *4. Any conventional machining of waveguide blocks can be done by our*
> *shop here at NRAO.*

> 5. I would enjoy the opportunity to work closely with your group on the designs of new multipliers for higher frequency operation (100-900 GHz range). Can we begin to look into higher frequency designs under this proposal? I would personally like to see this work evolve into a collaboration rather than a formal contract.
>
> I look forward to your reply.
>
> Best Regards,
>
> Richard
>
> ---
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fgc_references.doc	**Name:** fgc_references.doc **Type:** Microsoft Word Document (application/msword) **Encoding:** BASE64

1. "Millimeter-Wave GaAs Monolithic Multipliers," J. Papalymerou, J. East, L. Katehi, M. Kim and I. Mehdi, presented at International Microwave Symposium, June, 1998, pp 395-398 in conference digest, volume 2
2. "W-Band Finite Ground Coplanar Monolithic Multipliers," J. Papapollymerou, F. Brauchler, J. East and L. Katehi, IEEE Transactions on Microwave Theory and Techniques, vol. 47, no. 5, May, 1999, pp614-619.
3. "GaAs vs. Quartz FGC Lines for MMIC Applications," J. Papapollymerou, , J. East and L. Katehi, IEEE Transactions on Microwave Theory and Techniques, Nov. 1998, pp 395-398.
4. "W Band Monolithic Multipliers," Fred Brauchler, John Papapolymerou, Jack East and Linda Katehi, 1997 International Microwave Symposium Digest
5. "W-Band Finite Ground Coplanar (FGC) Line Circuit Elements," F. Brauchler, S. Robertson, J. East and L. Katehi, 1996 International Microwave Symposium Digest