# A LIGHTWEIGHT ACTIVE ANTENNA ARRAY USING MINIATURE BERYLLIA AMPLIFIERS

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## Summary

A planar active antenna array design combines miniature beryllia amplifiers using batch process techniques with an open-celled microstrip antenna. A thin, very light active antenna subarray using these technologies has been developed and tested.

## Introduction

Most solid-state radar and microwave communications systems require more output power than can be generated by single devices. This has prompted the development of power combining techniques using direct device paralleling in the final amplifier stages and hybrid coupler or cavity combining of many amplifier outputs. A more efficient and lightweight method uses many amplifiers that are integrated with and individually excite portions of an antenna aperture. This active antenna approach eliminates the hardware and associated losses of other techniques through post-radiation power combining. This paper describes a lightweight planar active antenna array that combines a new amplifier technology with a microstrip antenna developed specifically for active arrays.

## Antenna

A linearly polarized microstrip patch antenna (Fig. 1) was developed specifically for lightweight active array applications. The antenna uses a thin slice of low loss open celled dielectric made of aramid fiber material (Hexcel* HRH-10) to support the patch array. The array size, which is determined by the system design, is 2x2 elements for this demonstration model. Each element presents a feed impedance of a few hundred ohms, which is matched through the rf distribution network located on the plane of the elements. The element array and feed network are made of etched 4-mil metal. The array is centrally fed by a 50-ohm connection passing through the ground plane. An antenna constructed with low dielectric ($\varepsilon_r = 1.4$) open celled material has several distinct advantages over planar antennas using higher dielectric materials such as Duroid.** Heat, generated by amplifiers mounted on the reverse side of the antenna, is convected and radiated from the antenna side as well as the amplifier side of the active array. Also, the Hexcel material is approximately 15% the weight and has less than half the loss of Duroid, and finally, for a .032" thick dielectric, the lower Q of the Hexcel structure results in improved bandwidths as shown in Fig. 2. The measured bandwidth for a VSWR of 2:1 is 700 MHz as compared to 450 MHz for the equivalent 2x2 array on Duroid.

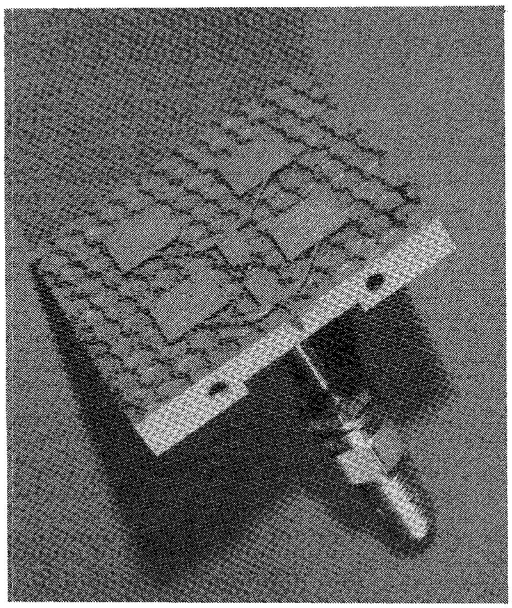


Fig. 1. Linearly Polarized Microstrip Antenna

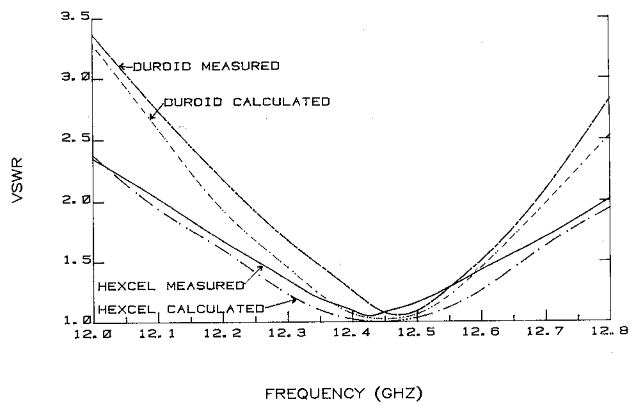



Fig. 2. 2x2 Patch Antenna Bandwidth

## Amplifiers

A new miniature beryllia circuit (MBC) technology[1] has been developed that combines many of the advantages of both the hybrid and monolithic circuit techniques.[2] A complete MBC amplifier exclusive of FET is fabricated on a single beryllia (BeO) substrate that is selectively glazed to accept thin film circuit tuning and biasing elements. Figure 3 is an example of a 0.2"x0.2" 12 GHz MBC amplifier including a 2400 μm FET (MGFC 2124)*** that is flipped and thermocompression bonded onto an unglzed portion of the BeO. The BeO, with the thermal conductivity of aluminum, provides an excellent device heat sink. The thermal expansion coefficient also closely matches that of GaAs. The FET sources are grounded by a low inductance, integral copper septum extending between the upper and lower surfaces of the BeO substrate. The septum also serves as the ground return for the thin film capacitors. All wire bonds, used in this design for capacitor interconnections, will be replaced in the future with metal air bridges. This MBC technology has the potential for inexpensive batch circuit fabrication resulting in highly reproducible circuit performance. This is a prerequisite for active antenna arrays.

* Hexcel Corporation

** Rogers Corporation
*** Mitsubishi Corporation

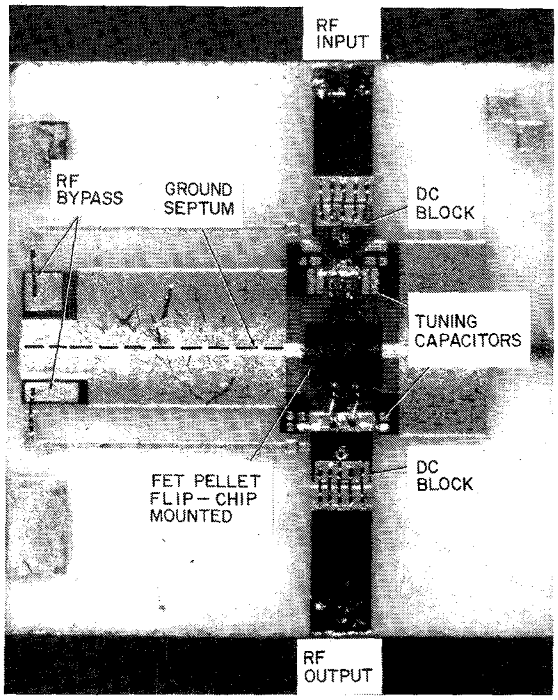



Fig. 3. MBC Amplifier

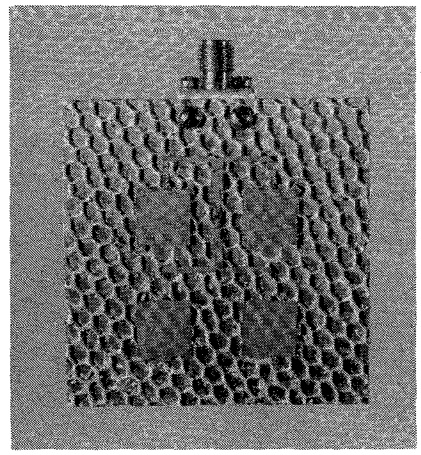
The feasibility of the MBC technology has been demonstrated with highly encouraging results. Initial performance for single stage amplifiers designed for various system applications range from a 38% power added efficiency at 12 GHz and 135 mW output, using an MSC88202****, to a power output of 2 watts at 10 GHz with 23% efficiency with an MFGC2148. Typical performance of a circuit designed for a 2400 μm device at 10.5 GHz is 600 mW output with 5.5 dB gain and a power added efficiency of 33%. An amplifier of this type tuned for 12 GHz operation was chosen for the demonstration active antenna subarray. The single stage input and output matching of these designs result in 1 dB bandwidths of approximately 600 MHz, which is sufficient for many system applications. All of these results include the losses of the input and output SMA connectors, which will be removed before the circuit is inserted into the active array.

## Active Antenna Subarray

The demonstration active subarray combines the MBC amplifiers with the Hexcel antenna in the thin, lightweight structure shown in Fig. 4. The impedance of the amplifier-antenna interface is fixed at 50 ohms not only to simplify the component testing but also as a good intermediate value for best power transfer between the few ohms of the FET output and few hundred ohms of the antenna resonators. The amplifier substrate is directly mounted to the .03" thick gold plated aluminum ground plane using a compliant solder. Metal DC bias lines are plated onto a thin polyimide film that is bonded to the ground plane. The complete 2"x2" subarray is less than 1/16" thick and weighs 6.5 grams with connector removed.

## Conclusion

The active antenna array concept is an efficient and lightweight method for generating high rf power for communication and radar systems. Active planar arrays having weights of approximately 0.25 pounds per square foot of aperture are now feasible through the combination of the new MBC processing technology with a low mass microstrip patch resonator antenna design. Batch processed MBC amplifiers are particularly well suited to the active array requirements for high volume low cost production with reproducible performance. Future mobile, airborne and spaceborne systems that specify efficient, light-weight high microwave power generation are the target applications for the planar active antenna array.



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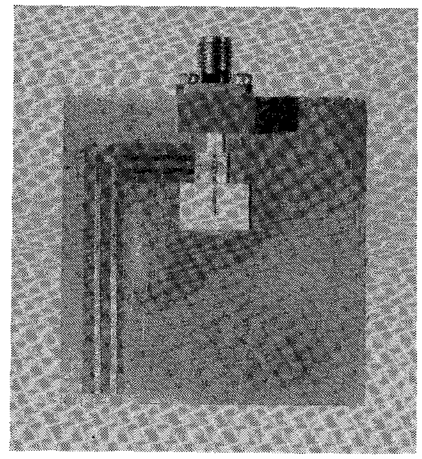

AMPLIFIER

| | | | |
|---|---|---|---|
| Device | MSC88202 | Size | 2" x 2" |
| Antenna | 0.031" Hexcel | Weight | 6.5 gm |

Fig. 4. Active Sub-Array

## References

1. F. N. Sechi, R. Brown, H. Johnson, E. Belohoubek, E. Mykietyn, and M. Oz, "Miniature Beryllia Circuits - A New Technology for Microwave Power Amplifiers," RCA Review, Vol. 43, pp 363-374, 1982.

2. R. S. Pengelly, "Hybrid vs. Monolithic Microwave Circuits - A Matter of Cost," Microwave System News, Vol. 13, No. 1, January 1983, pp. 77-114.

**** Microwave Semiconductor Corp.