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Ignitability of Anechoic Chamber Foam by Electric Currents

M. A. PLONUS

Abstract—Anechoic chamber foams are easily ignited by passage of current through them. Two distinct ignition processes can be observed. The first is a contact fire that results when two sharp points which are at a potential difference of more than 100 V touch the conducting foam. The second is an I^2R heating of the interior of the foam which begins with smoldering, then a glowing chunk of foam inside the material which grows and usually ignites. An unexpected by-product of burning carbon-impregnated foam is the voluminous release of dense toxic smoke (Tatem and Williams [1]).

On March 27, 1973, a small anechoic chamber was destroyed at Northwestern University when the absorbing foam ignited. The cause was not known immediately, as ordinary precautions against fires were always in effect. The outside of the chamber was made of wood, hence all electrical equipment inside or outside the chamber was always adequately fused, soldering irons were used at a safe distance, etc. Inquiries at that time revealed that several other chambers had been destroyed by fires, with the causes of the fires unknown. On November 15, 1973, the anechoic chamber and an adjacent room at the Naval Research Laboratory were severly damaged by fire. On February 5, 1974, the chamber at the Naval Air Rework Facility in Alameda, Calif., was destroyed by fire. Once a fire starts in an anechoic chamber, the voluminous release of high concentrations of toxic gases makes usual fire-fighting efforts unsuccessful, which ensures the complete destruction of the facility. As these accidents seem to occur often enough to be significant, we decided to present the results of our investigation following the fire here.

A search of the advertising brochures and specification sheets of several anechoic chamber foam manufacturers showed that they did not contain warnings or special precautions to be taken against flammability of these foams. The impression one gets is that ordinary precautions that one would take against other flammable materials such as loosely stacked papers, wood shavings, or even dry wood would suffice. Our own tests revealed that these were indeed not highly flammable materials. A lighted match would ignite the foam, but not any faster than it would newspaper. The rate of burning was also comparable (usually less) to that for ordinary loosely packed paper, except for the production of dense smoke. Another test involved a soldering iron. We were not able to ignite the foam by inserting a hot 600-W soldering iron into it.

In the accident at Northwestern University, there were some indications that the exposed terminals of a klystron might have come in contact with the foam inside the chamber, thus the possibility of electrical fire was investigated. This indeed turned out to be the case. The student doing an experiment reported that, just before the fire, the 0–20-mA meter indicated more than 20-mA emitter current (normal current is 5 mA) on the klystron power supply, which was located outside the chamber. Apparently, equipment mounted on a rotating platform, which included a klystron, had touched the conducting foam as it moved past the chamber wall and had ignited it.

Measurements on the foam showed that it is a much better conductor than first anticipated. Again, warning in the sales literature that this is a highly conducting foam rather than an insulating foam was absent. Anechoic chamber foam derives its RF absorbing properties from carbon impregnation. The resistivity turned out to be 10 $\Omega \cdot$m and dropped by a factor of 7 when the foam was compressed 2:1. The ease of electrical ignition of this foam was unexpected and surprising. We concluded that this poses a major fire hazard of this product as its customary use is near electronic equipment. Two distinct processes can be observed.

1) When two wires or two points which are at a potential difference of more than 100 V touch the foam, the flakes of foam that are touched carry the entire current of the completed circuit and virtually explode as the result of heating. This usually starts a small flame. The higher the potential and the sharper the contacting points, the more sudden is the process. It is largely independent of separation distance of the contact points. The effectiveness of the contact fire is comparable to that of a lighted match, both provide a local fire which starts to spread at a rate which is easily controlled in its initial stages. If not checked quickly, the production of dense smoke will usually prevent extinguishing of what probably is still a small flame. We concluded that electrical contact fire was the cause for the fire here, as the fuse on the klystron power supply was found afterwards to be blown.

2) When two contact points are driven into the foam, if an immediate electrical contact fire does not result, either because the voltage is not high enough or the contacts are blunt, the result will be an I^2R heating of the interior of the foam. Maximum heating will take place somewhere in the interior, since the volume of the foam forms a distributed resistor between the contact points with a minimum resistance path somewhere toward the interior, and since the heat generated is not readily conducted to the surface. Again, this process is largely independent of contact separation, especially for large blocks of foam. The first observation is smoke pouring out of the foam as its interior starts to smolder, and burn. If the interior is then exposed, a red-hot smoldering foam is found which usually does not catch fire. It is expected that if the current is not turned off, the glowing, but oxygen-starved, foam in the interior will ignite when it spreads close enough to the surface.

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The author is with the Department of Electrical Engineering, Northwestern University, Evanston, Ill. 60201.

Full-Band Staggered-Gain Gunn-Effect Amplification in *Ka* Band

J. G. DE KONING, R. E. GOLDWASSER, R. J. HAMILTON, JR., AND F. E. ROSZTOCZY

Abstract—The feasibility of full-band low-noise instantaneous amplification in *Ka* band has been demonstrated using a staggered-gain amplifier technique. A simplified analysis of the overall gain variations in this two-stage amplifier is used to calculate the minimum isolation levels needed to meet a maximum allowable ripple. Using this technique, 10 ± 2.2-dB gain has been obtained from 26.6–39.4 GHz.

During the past three years, the development status of Gunn-effect amplifiers for millimeter-wave frequencies has advanced rapidly. The first narrow-band low-power *Ka*-band Gunn-effect amplifiers have been followed by communications-type amplifiers with bandwidths up to 4 GHz, saturated power outputs of 250 mW, and gains of up to 30 dB at the 100-mW output power level [1]–[4]. This letter discusses the development of a 10-dB-gain Gunn-effect amplifier module to cover the entire *Ka* band. In order to achieve full-band instantaneous gain at millimeter frequencies, a staggered-gain configuration is employed to circumvent the unavailability of full-band circulators above 26.5 GHz.

The bandwidth over which instantaneous gain can be achieved in a single-stage circulator-coupled negative-resistance amplifier is determined by the negative-resistance bandwidth of the active device and by the usable bandwidth of the circulator. In cases where the required

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The authors are with Varian Associates, Palo Alto, Calif. 94303.