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POTENTIAL ARC HAZARD PRODUCED BY HANDLING CONNECTORS WHILE OPERATING PULSED MICROWAVE EQUIPMENT

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ABSTRACT

Large microwave pulses with low average power can cause arcs between the sharp center pins of N-type connectors and biological tissues. These arcs may have enough energy to ignite volatile vapors.

Introduction

Large microwave pulses of low average power (1.5 W) can cause arcing when uncoupled N-type connectors are touched by the hand. CW microwaves of the same average power do not cause arcing. This phenomenon is important because radio frequency arcs can ignite volatile vapors.[1,2] There are several situations where cables carrying pulsed microwave power may be handled in the presence of volatile vapors with the power on. These include biological laboratories where volatile vapors may be present, and may include military and industrial environments as well. It should be noted that handling connectors carrying hundreds of watts of average power is a direct burn hazard in either the pulsed or the CW case, and should be avoided. Here we will examine the case of pulsed microwaves where the average power is low, but the peak power may be high enough to ignite volatile vapors.

This phenomenon was first noticed as a chirping sound when handling cables with the power on during experiments on red blood cells[3] and later on animals in waveguide cages.[4] At first we did not associate the sound with the microwave power itself, but later after further investigation we noticed that the pitch of the sound was directly related to the pulse repetition rate, increasing with increasing pulse rate. The sound was much more noticeable when we began using some new cables with crimp on connectors that had sharper center pins than the older connectors we had been using.

Experimental Results and Discussion

We found that an average power of only 1.5 watts created an arc between the sharp tip of the center pin in the N-type connector and a thumb or finger in contact with the outer rim. The sharper the center pin the more likely it was to create an arc. If the finger is held too long or too close to the connector, the pulsed microwaves can cause pain. If CW is used instead of pulsed microwaves there is no arcing, but prolonged contact still causes pain.

A thin (0.05 mm) rubber glove filled with saline can be used in place of the finger to produce arcing. However, if the glove is filled with glycerol the arc is not formed. If the glove material is too thick (0.18 mm) the arc is also suppressed. The fact that glycerol does not lead to an arc is not surprising since the high dielectric constant of the water causes the glove to act as a shunt, while the low dielectric constant of the glycerol does not.

This arc phenomenon is one of the few cases besides microwave hearing where pulsed microwaves can produce an effect on biological tissues that CW microwaves with the same average power can not. In the case of microwave hearing, minute sound waves are created during the pulse by the sudden heating of the tissue.[5] In the case of arc production, the current flows through a progressively smaller contact area and, as separation begins, heat is generated, allowing electron emission to occur. The emitted electrons are accelerated across the gap creating the arc.[2] Dielectric breakdown may also be important in the noncontact case.

It is likely that little hazard exists in most cases. However, the previous studies[1,2] were limited to the CW case. Our work has shown that arcing can occur with large microwave pulses even when the average power would be far too low to create arcing in the CW case. Blanc et al. have shown that diethyl ether-air mixtures can be ignited by spark discharges with energies of only 0.2 mJ.[6] Each individual pulse in our experiments exceeds this level substantially. Also, we are using a train of pulses rather than a single discharge. It has been shown that pulses with typical radar repetition rates of around 1000 are more effective than individual pulses in producing arcs.[7]

A typical average power in our study was 1.5 W with a peak power of 1.5 kW, a 1 μs pulse length, a pulse rate of 1000 pulses per second and a duty cycle of 0.001 at 2450 MHz. We used cables terminated with N-type connectors in contact with rubber glove phantoms filled with physiological saline, as shown in Figure 1, positioned to simulate finger contact. Measurements on the phantom were more repeatable than on an actual finger. One problem with the phantom, however, was the formation of pinhole leaks in the rubber at the point of contact with the center pin.

The arc at the point of contact was quite short. The longest arc that could be drawn out by holding the phantom slightly out of contact with the center pin was approximately 0.5 mm. The length of arc was strongly dependent on the sharpness of the center pin. It is probable that configurations other than the N-type connector might produce even longer arcs. In fact, the significance of these results extends to all kinds of microwave devices and fixtures.

In order to calculate the power absorbed by the arc and phantom we measured the forward and reverse power. These measurements were made with two Hewlett Packard model 430A digital power meters and a 20 dB dual coupler. We also monitored the pulse shape with a diode detector and a forward 20 dB coupler. The pulse shape and the forward power changed somewhat when the phantom was in place, indicating that the isolation from the source was not perfect. The pulse generator was a Micon pulsed source with built in isolators. We also used an Epsco pulsed source with an external isolator for some experiments.

The power measurements were:

1.5 W forward,

0.47 W reverse.

Thus, approximately 1.0 W of power was dissipated in the arc and phantom. This represents 1.0 kW of peak power and an energy per pulse of 1.0 mJ. Assuming all of the energy went into the arc this would be 5 times the energy needed to ignite ether vapor.[6]

The general equation for ignition can be written as:[8]

$$V_c J \rho C_p (T_f - T_i) = \sigma E_c$$

where:

- E_c = minimum amount of energy
- V_c = minimum critical volume
- C_p = specific heat
- J = mechanical equivalent of calorie
- T_f = flame temperature
- T_i = initial temperature
- ρ = density
- σ = fraction of energy available for ignition

The value of σ is difficult to determine experimentally. However, even for values substantially less than 1, the possibility of ignition exists. Thus it appears that arcs between the hands and connectors carrying large microwave pulses of low average power could ignite volatile vapors under the right circumstances. The exact circumstances would depend on the energy in the arc, the volume of the arc, and the time duration of the arc. The pulse repetition rate may also be a factor.

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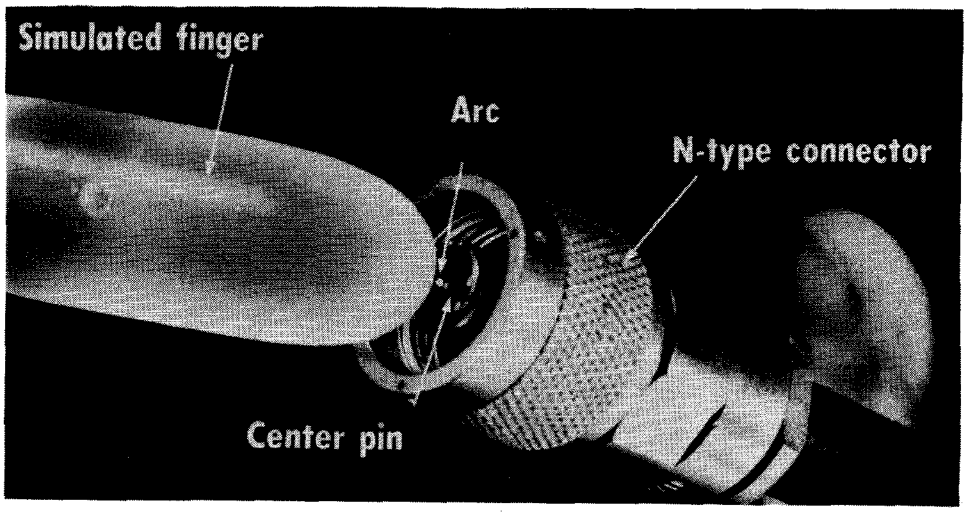

Figure 1. N-Type Connector with Finger and Arc