TRADE-OFFS ON ANTENNA FABRICATION

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ABSTRACT

This paper addresses the future military munitions' system requirements for antennas in terms of the existing versus new fabrication technology. The antenna requirements of the future smart munitions will be GPS for precision guidance and TM for system performance testing. The environmental requirements remain the same; large temperature operating range with operation at high temperatures and high shock capable. As usual, the munitions are getting smaller, frequency bandwidth is getting larger, and the cost of the antennas must be minimized in production quantities. In particular this paper compares the existing antenna fabrication technology of Teflon based dielectric printed circuits versus multilayer alumina in the green state, a technology that has been perfected for fabricating microwave integrated circuits (MIC's). The trade-offs that will be addressed are temperature, shock, cost, tunability, loss, size, dielectric constant, and frequency bandwidth.

There has been a significant effort to miniaturize the GPS and TM antenna using higher dielectric constant materials. The most popular direction of this effort has been to use ceramic impregnated Teflon. The ultimate temperature performance is the material with a dielectric constant around 2 since this material exhibits a very low coefficient of change with temperature. Materials are available with nominal dielectric constants of 6 and 10 to reduce the size of the antenna but the coefficient of change with temperature is very large and leaves these materials marginal for military temperature ranges. There have also been two other problems with Teflon based printed circuit boards, forming and bonding the boards in a 3D shape and homogeneity of the dielectric constant in the board and after bonding. These problems usually make tuning a requirement and drive the cost of antenna fabrication up.

There has been a revolution in MIC's. The circuits are now being made with multiple layers of ceramic (alumina) with interlayer conductive connections and a nominal dielectric constant of 10. The layers are formed in the green state and fired at high temperature and the resulting alumina substrate has a very low coefficient of change with temperature and low loss. Since this procedure is now beyond development, the cost is low and the volume capability is high. Another significant point is that the part can be any shape since the substrate is done in the green state (formable) and then fired.

KEY WORDS

Antenna, transmit antenna, TM antenna, GPS antenna, MIC, LTCC

INTRODUCTION

The current antennas for high performance munitions are made from Teflon based material to withstand the sever environment. Variation with temperature and lack of homogeneity makes these dielectrics produce antennas that need tuning after etching for thin dielectrics. Efforts to make the antennas smaller has resulted in using Teflon dielectric impregnated with very high dielectric substances such as Titanium dioxide. This has resulted in an effective higher dielectric with resulting smaller antennas but the change of dielectric constant with temperature has made these materials unacceptable for military temperature range requirement. Therefore we have two problems: (1) homogeneity of the dielectric for a complex 3D antenna structure and (2) need for a higher dielectric constant for smaller antennas. The driving factor is cost, tuning means higher cost.

Current microwave circuits are being produced by using alumina in the green state, adding circuitry, firing the substrate, and adding other elements. It would appear that the techniques developed for mostly 2D applications could be used to fabricate high performance antennas in 3D applications that would be smaller due to a higher dielectric constant and not require tuning due to a better control of the dielectric. The results should be a lower cost antenna in production

This report looks at this situation and the problems that must be solved to prove that alumina antenna circuits can survive in a military environment.

BODY

EXISTING ANTENNAS - The existing antennas for a GPS or TM applications usually consists of several layers of Rogers Corporation's RT/duroid 6002. Several layers are required to achieve the minimum bending radius for the dielectric. The RT/duroid 6002 is used because it has a proven track record of very low antenna resonate frequency shift due to temperature change. The problem with current antennas is that complex 3D shaped antennas cause the dielectric constant to not be homogeneous or consistent antenna to antenna for small sized antennas so that tuning is required to meet frequency bandwidth requirements. The problem is exasperated by requirements to make the antenna smaller. Going to a higher dielectric can make the antenna smaller but for example going to Rogers Corporation RT/duroid 6010 increased the dielectric from 2.94 to 10.2 but with a change due to temperature of from 12 ppm/degC to -425 ppm/degC (Reference 1 and 2). Unless the frequency bandwidth is very small, this antenna will fail to meet the temperature requirements. Most of the antennas do have a protective cover made from Rogers Corporation RT/duroid 5870. This material has a proven track record of withstanding very high temperatures due to the dielectrics ability to abate material off the surface of the antenna that reduces the antenna's temperature.

EXISTING MICROWAVE COMPONENTS - Mini-Circuits has developed green tape low temperature co-fired ceramic (LTCC) techniques to produce many 2D product lines that are reproducible and more importantly, low cost (Reference 3). The alumina ceramic has the benefit of a high dielectric constant of 9 and a low loss and low change of dielectric constant with temperature with a high temperature limit of 1650 degC (Reference 4).

FABRICTION TECHNOLOGY - The basic green tape LTCC fabrication technology has been developed by DuPont (Reference 5). The fabrication technique if mature but for the most part has been for 2D structures.

PROBLEMS TO BE SOLVED - Going to antennas fabricated with green tape LTCC does hold a big benefit but several items must be solved. The first is going from a 2D to a 3D structure, will this cause a problem in homogeneity as it does in Teflon based dielectrics. The second and most important problem is will alumina antennas withstand shock as well as Teflon based antennas. Maybe using shock absorbing materials to mount the ceramic antennas will make them shock resistant but this must be tested.

CONCLUSION

The potential of using green tape LTCC fabrication techniques to reduce the cost and size of high performance antennas appears to be significant. The electrical performance of the higher ceramic dielectric should be comparable to the temperature compensated Teflon dielectric over military temperature ranges.

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