THE MEASUREMENT OF RF-ANTENNA NEAR FIELD PATTERNS USING LIQUID CRYSTAL SENSORS

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Introduction

Present methods for measuring antenna near field RF patterns utilize a point to point probing technique. The results from this method are somewhat unsatisfactory due to the coupling between the antenna and the probes. Secondary effects such as reflections also tend to confuse the data. In addition, the point to point probing of an antenna near field is a time consuming process during which the RF power level must be held constant.

The use of liquid crystal detectors makes real time near field measurements possible. This method produces a visible image of the near field pattern which can be photographed or simply viewed. Distortion of the near field can be minimized through the use of liquid crystals as compared to the probing methods. Another advantage offered with liquid crystals is the possibility to customize the measuring apparatus to any particular application.

Description of Liquid Crystal Materials

For some organic materials the change of state from the solid to the liquid phase is not a singular transition process. That is, under certain conditions a mesophase exists which is fluidal in nature, however, it is not a true isotropic liquid but has a molecular orderliness. The term "liquid crystal" is a popular descriptive term for this type of mesophase. The various mesophases known to exist are termed the Nematic, the Smectic, and the Cholesteric phases, being listed in order of increasing molecular orderliness. The paper will give more detailed information on the liquid crystal properties. For the present discussions it is only important to note that if for a particular cholesteric liquid crystal material the angle of the incident light is kept constant, then the reflected color is a function of temperature only. A very thin film of these liquid crystals (approximately 1 to 2 mils) produces the most brilliant colors. Various esters can be mixed to produce color play at any temperature up to 250°C. Iridescence can occur over temperature ranges of 1 to 50°C. The sequence of color play procedes with increasing temperatures from red at the lowest temperature through yellow, green to blue. Usually a black background is used to aid in color viewing and to give a black image at both ends of the color play range.

Cholesteric liquid crystals are obtainable in various forms. There are pure bulk liquid crystals, others are mixed with a solvent, and a third form is an encapsulated slurry which is also available in sheet form. The encapsulated type consists of liquid crystal spheroids approximately 20 microns in diameter contained in plastic shells. The bulk liquid crystals can be easily applied (with a brush for example) whereas the mixed liquid crystals are sprayed. The encapsulated slurries can be applied in the same manner as the liquids. Liquid crystal sheets consist of thin mylar substrates coated with the encapsulated slurry and backed with a black dye.

Experimental Program

The intent of the experimental program described in the paper was to develop a simple and reliable technique for measuring antenna near field RF patterns using liquid crystal sensors.

Special detectors were designed, which when placed in an antenna near field would convert incident RF energy to heat energy producing a two dimensional temperature profile in the liquid crystal layer and a resulting color pattern.

Design and Performance Considerations

The color pattern obtained with liquid crystals is directly related to the RF field to be measured. However, special consideration must be given to the thermal environment of the liquid crystal detector. Errors may be introduced by variable heat transfer effects.

For safety reasons a low power (≃ 1 watt) RF source was selected. This source along with a variable attenuator was connected to an open-end rectangular waveguide. The near field pattern from such a waveguide can be determined analytically thus allowing comparisons with the measured data. Design studies indicated that with the low power RF source insufficient energy would be absorbed in a thin liquid crystal film to produce the desired color response. Therefore, a resistive substrate was devised, upon which the liquid crystal film was deposited. The substrate must be sufficiently thin so that the temperature profiles in both the liquid crystal layer and the substrate layer are essentially identical. The substrate resistivity was selected so that it was compatible with the power source and the ambient temperature environment. A controlable dc bias current was passed through the substrate in order to set detection threshold conditions. Another design consideration was to minimize the reflection of RF power back into the waveguide thus distorting the near field pattern. Figures 1 and 2 show the construction and orientation of the liquid crystal detector.

Calibration

The liquid crystal detector was calibrated with different RF power levels using the source attenuator. During calibration the detector was placed a fixed distance from the open ended waveguide. The source attenuation was decreased from initially high to lower values thus determining the attenuation at which the predominant colors sequentially appeared at the center of the pattern (red through blue). Attaching a relative power level to each predominant color assumes that the heat transfer coefficient from the detector to its ambient is constant over the detector surface.

Measurements and Data Reduction

The near field pattern of the open waveguide was measured by taking color photographs of the color display on the detector. Ektacolor type S film used with an electronic flash was found to give a true color rendition. The patterns appear as concentric color bands which grow in radius with decreasing source attenuation. The test apparatus is shown in Figure 3.

Several patterns were photographed at different stages of pattern growth corresponding to decreasing values of attenuation. The attenuation readings (in decibels) were converted to linearized power ratios by assuming the power input into the attenuator to be a constant. The power ratios for each pattern were then normalized with its maximum value (centerline value). The diameters of the color bands were measured from the photographs and converted to the corresponding angles from the centerline of the aperture of the open waveguide. Photographs of the open ended waveguide and a typical pattern are shown in Figures 4 and 5 respectively.

With this data, the measured power levels as a function of angle could be compared with the analytically derived values.

Results and Discussions

The results of the test measurements shown in Figure 6 indicated that the experimental results (as determined with the liquid crystal detectors) agree with the analytical values to within ±15 percent. This discrepancy is caused by a variety of effects.

Some scatter in the data indicates that the calibration method should be improved. For data taken at large distances from the centerline, the calibration appears to be slightly incorrect, indicating possible small variations of the heat transfer coefficient across the detector surface.

Improvements in the detector construction and its calibration are outlined.

Summary

To summarize, an improved method has been developed to measure near field RF patterns using liquid crystal detectors; the measurements agree very well with analytical calculations. Maximum deviations were found to be within ±15 percent. Further improvements in the measurement techniques are possible. The liquid crystal technique of measuring near field antenna patterns certainly represents a major improvement over the previous probing methods. It is simple, fast, inexpensive and reliable, to mention only a few of its advantages.

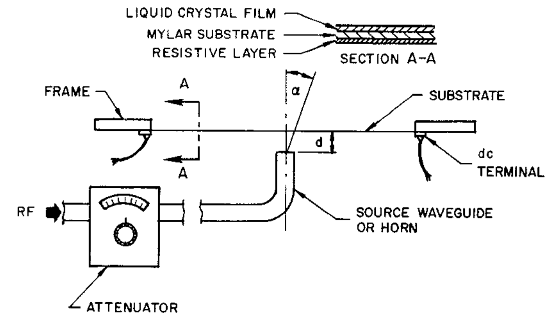

FIG. 2. CONFIGURATION OF DETECTOR AND RF SOURCE

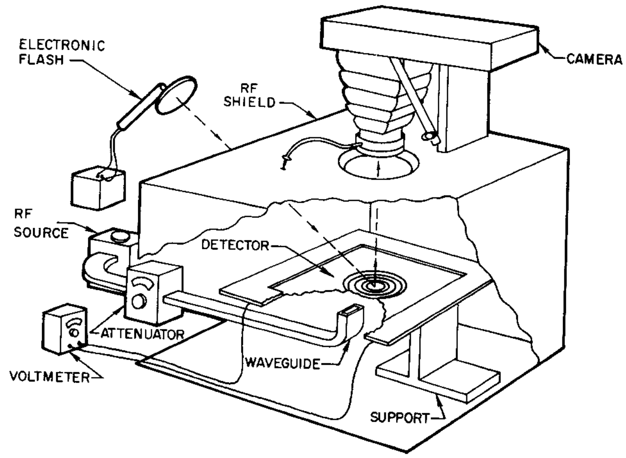

FIG. 3. ARRANGEMENT OF TEST APPARATUS

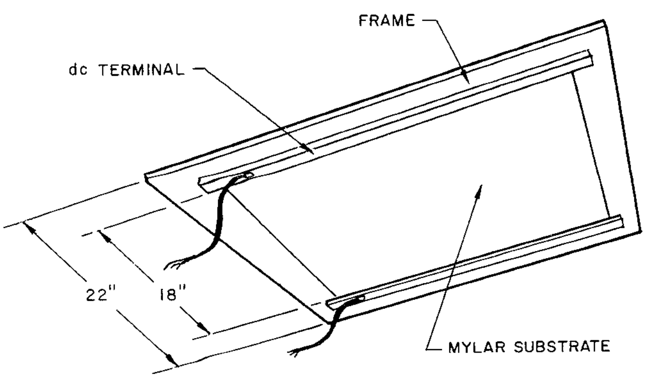

FIG. 1. LIQUID CRYSTAL DETECTOR

FIG. 4. OPEN-ENDED WAVEGUIDE RF EMITTER AND SCALE

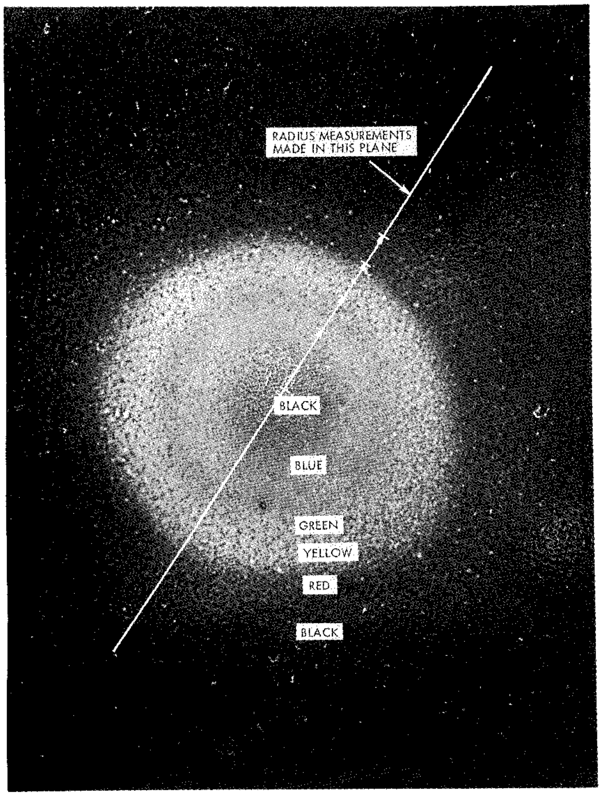

FIG. 5. LIQUID CRYSTAL COLOR PATTERN WITH d = 7/8 INCH AND 2 dB ATTENUATION

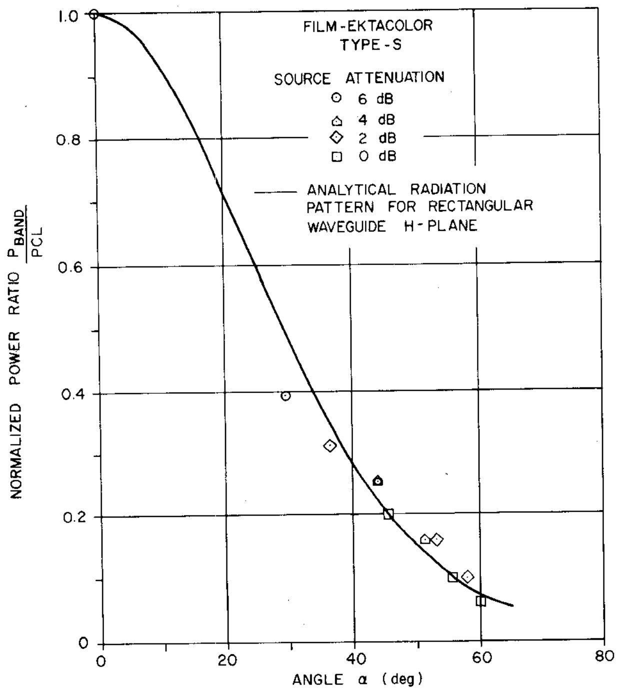

FIG. 6. MEASURED RF NEAR-FIELD PATTERN AND COMPARISON WITH ANALYTICAL PATTERN FOR DETECTOR DISTANCE d = 7/8 INCH

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