proposed dipole structure is mainly composed of two bent radiating arms and a narrow shorting strip, and can easily be fabricated by cutting a flat, rectangular metal plate at low cost. Good omnidirectional-radiation characteristics across the operating band have been observed too. Overall, the antenna is very suitable for some WLAN applications in terms of the fabrication cost and the antenna radiation performance.

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POLYANILINE AS AN AUTOMATIC BEAM STEERING MATERIAL

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ABSTRACT: *This study deals with a preliminary study of automatic beam steering property in conducting polyaniline. Polyaniline in its undoped and doped state was prepared from aniline by the chemical oxidative polymerization method. Dielectric properties of the samples were studied at S-band microwave frequencies using cavity perturbation technique. It is found that undoped polyaniline is having greater dielectric loss and conductivity compared with the doped samples. The beam steering property is studied using a perspex rod antenna and HP 8510C vector network analyzer. The shift in the radiated beam is studied for different d.c voltages. The results show that polyaniline is a good material for beam steering applications.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 422–425, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23115

Key words: *polyaniline; tapered dielectric rod antenna; beam steering*

1. INTRODUCTION

Antenna, a device for transmitting and receiving signals, is a major part of any communication system. A major application of antenna is in the radar system where the antenna radiation beam is directed along a specific direction towards a target such as an enemy aircraft. Because of the nature of the target and also to improve the efficiency of the system, the radiated beam has to be pointed along different directions. A simple method is to move the antenna mechanically. As this is not a convenient method, nonmechanical beam steering antennas were developed. These involve frequency controlled as well as voltage controlled beam steering antennas [1, 2]. How ever they are expensive and requires complex circuitry. These days' researchers have been focusing on reducing the cost of beam steering systems. In this study, a low cost method for beam steering is presented using conducting polyaniline at microwave frequencies.

Microwaves constitute only a small portion of electromagnetic spectrum, (300 MHz to 300 GHz) but their uses have become increasingly important in the modern world. The dielectric parameters over a wide range of temperature on low loss dielectrics are needed to assess their suitability for use in telecommunications, dielectric waveguides, lenses, radomes, dielectric resonators and microwave integrated circuit substrates and on lossy materials for estimating their heating response in microwave heating applications. Microwaves only partially reflect from and freely propagate through dielectric materials such as ceramics. It is the combination of these two conditions, which allowed the development of a method that permits the measurement of dielectric properties and physical dimensions.

Polyaniline has been known for more than a century [3], and is still of interest both academically and industrially. It is inexpensive to produce relatively light in weight, corrosion resistant and exhibits good environmental stability. Interesting applications of polyaniline and its derivatives in the areas of light weight batteries [4], electrochromic displays [5, 6], electroluminescent devices [7], electrochemical actuators [8], schottky diodes [9], gas separators [10], and photonic devices [11] have been reported. The studies on the dielectric properties of polyaniline especially at microwave frequencies gave way to their potential application in electromagnetic interference shielding [12, 13]. In addition, the dielectric constant of polyaniline is found to vary at microwave frequencies. This finds application in beam steering antennas where the antenna beam can be steered by changing the operating frequency. In case the change in the operating frequency is not desirable, we have to resort to other methods.

2. EXPERIMENTAL AND THEORY

2.1. *Preparation of Polyaniline*

Polyaniline in its undoped state is prepared by the chemical oxidative polymerization [14] of aniline using ammonium per sulphate as the initiator. The reaction is carried out for 4 h. The precipitated polyaniline is filtered, washed with water and acetone and then dried. It is then finely powdered for further use. Doped polyaniline is also prepared by the chemical oxidation polymerization of aniline as described above, but in the presence of a 1 M acid. Here the acids used were hydrochloric acid (HCl) and perchloric acid ($HClO_4$).

2.2. *Dielectric Characterization of the Material Using Cavity Perturbation Technique*

The cavity perturbation technique is a highly sophisticated method for the evaluation of the dielectric property of the materials. The cavity resonator is constructed with a portion of a transmission line (waveguide or coaxial line) with one or both ends closed. The resonator can be either transmission or reflection type. There is a coupling device (iris) to couple the microwave power to the

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resonator. The length of the resonator determines the number of resonant frequencies. In this experiment, the measurements were made at room temperature using a transmission type S band cavity resonator excited with TE_{10p} mode by connecting it to an HP8510C network analyzer.

2.3. *Dielectric Property Measurement by Cavity Perturbation Technique[15, 16]*

The measurements were done at 25°C in S band (2–4 GHz). The real and imaginary parts of the relative complex permittivity are given by

$$\varepsilon_r' = 1 + \frac{f_o - f_s}{2f_s}\left(\frac{V_c}{V_s}\right), \quad \varepsilon_r'' = \frac{V_c}{4V_s}\left(\frac{Q_o - Q_s}{Q_o Q_s}\right)$$

The real part of the complex permittivity, ε'_r is generally known as dielectric constant and the imaginary part ε''_r of the complex permittivity is related to the dielectric loss of the material.

The loss tangent is given by $\tan\delta = \sigma + \omega\varepsilon''_r/\omega\varepsilon'_r$, Here $\sigma + \omega\varepsilon''_r$ is the effective conductivity of the medium. When the conductivity σ due to free charge is negligibly small (good dielectric), the effective conductivity is due to electric polarization and is reduced to $\sigma_e = \omega\varepsilon'' = 2\pi f\varepsilon_0\varepsilon''_r$.

2.4. *Construction of the Test Antenna*

The test antenna is constructed using a dielectric material such as perspex as it is easily available, light in weight, easy to handle and shape, low cost and has a low dielectric constant of 2.56. Perspex is cut in the form of a rod of rectangular cross section (cross sectional dimensions of 2.2 cm × 1 cm) and having a length of 15 cm, suitable for X-band operation. For perfect impedance matching, both ends of the rod are tapered. Figure 1, shows the basic configuration of the perspex rod. The short tapered end is the feed end and the other is called the free end. Waveguide feed is employed for simplicity and is excited by a proper source via a coaxial-to-waveguide adapter.

The radiation characteristics of such dielectric antennas have already been reported [17, 18]. To place the conducting polymer, a slit (having a length of 15 mm, width of 3 mm, and depth of 10 mm) is made at the center of broad side of the tapered perspex rod. The resulting set up is shown in Figure 2.

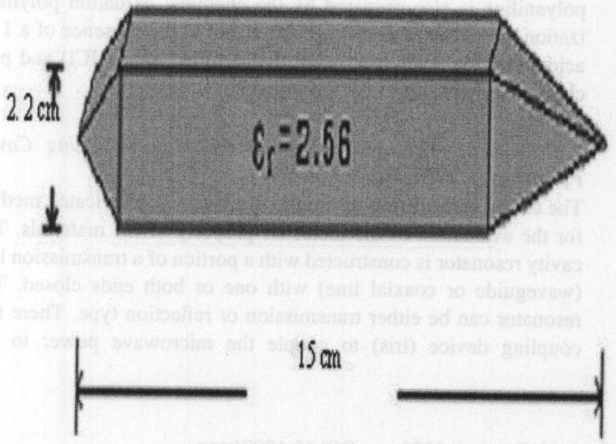

Figure 1 Schematic diagram of an X-band tapered dielectric rod antenna

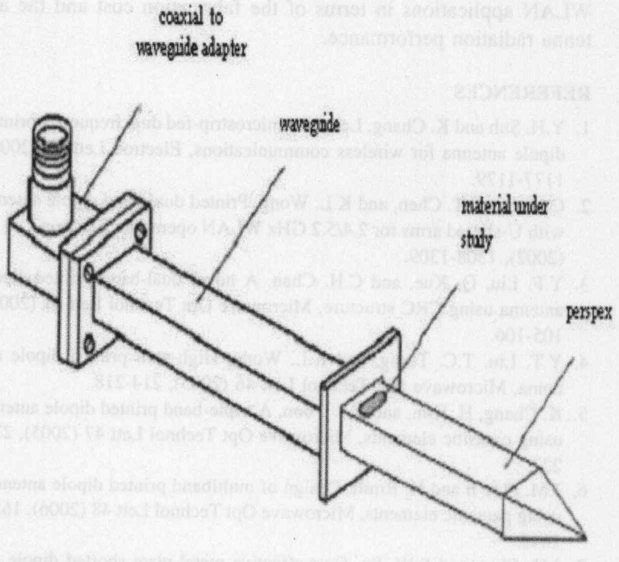

Figure 2 Receiver antenna setup showing perspex rod and the material under study

2.5. *Measurement of the Radiation Pattern*

The measurement setup consists of an HP 8510C vector network analyzer, S-parameter test setup, a wide band horn antenna (transmitter) and a turntable. The test antenna is configured in the receiving mode. It is placed above the turntable such that the axis of the transmitter and the receiver are along the same line. About 150–200 mg of the polymeric material is inserted into the slit and a d.c voltage is applied across it by means of two electrodes placed above and below the slits. The radiation pattern is measured for various voltages and the shift in the direction of the main beam is calculated.

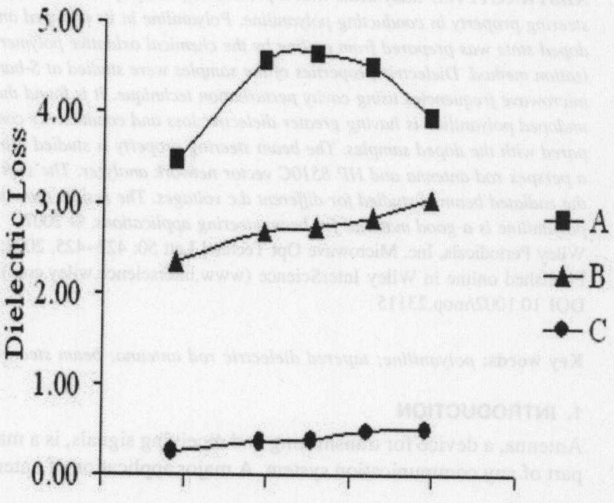

Figure 3 Variation of dielectric loss of doped and undoped polyaniline with frequency

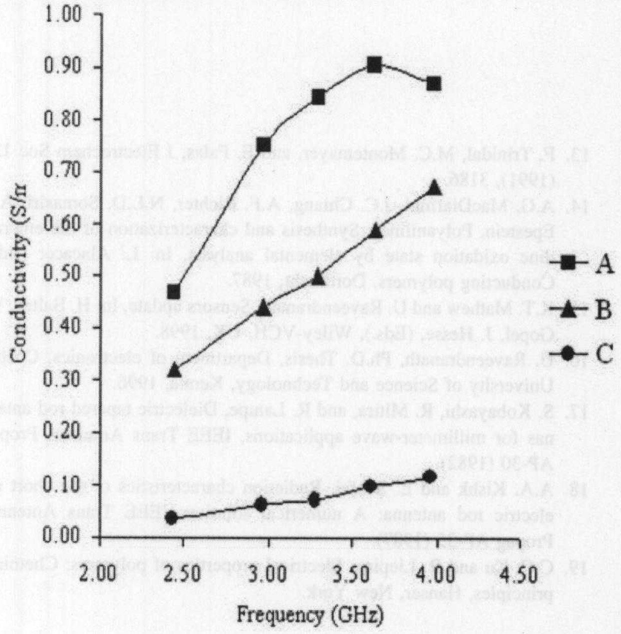

Figure 4 Variation of conductivity of doped and undoped polyaniline with frequency

3. RESULTS AND DISCUSSION

3.1. Dielectric Properties

Figure 3 shows the variation of the dielectric loss of the polyaniline in its undoped state as well as in its doped state with HCl and $HClO_4$ as dopants. Here after the undoped, $HClO_4$ doped and HCl doped samples of polyaniline will be represented in the figures by the letters A, B, and C, respectively. From the figure it is seen that the dielectric loss is greater for the undoped sample followed by the $HClO_4$ doped sample. In the microwave field, the dielectric loss occurs due to the dipolar polarization. For a dielectric molecule, the overall polarizability (α) is the sum of electronic (α_e), atomic (α_a) and orientation (α_o) polarization. Undoped polyaniline is nonpolar and in nonpolar materials, the orientation polarization is absent and the polarizability is solely due to electronic and atomic polarization. Doping by HCl or $HClO_4$ results in the transition of the polymer molecule from a nonpolar state to a polar state. When the polar molecules are large, the rotatory motion of the molecules is not sufficiently rapid for the attainment of equilibrium with the field. As a result there will be greater dielectric loss. This is the reason why $HClO_4$ doped polyaniline is having a greater dielectric loss than HCl doped sample.

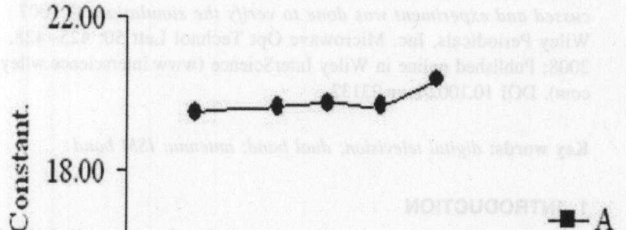

Figure 5 Variation of dielectric constant with frequency

As the microwave conductivity is directly related to the dielectric loss factor, it also shows the same behaviour as the dielectric loss. This is indicated in Figure 4. It should be noted that undoped polyaniline is having greater microwave conductivity. As already mentioned, $HClO_4$ dopant is having a greater size compared with HCl dopant. This causes a decrease in the average dipole moment (μ) per molecule of the polymer. Since the polarization is given by the equation [19], $P = n\mu$, where n is the number of molecules per unit volume of the dielectric, the decrease in the dipole moment leads to a decrease in the polarization. The polarization can also be represented as [11], $P = (\varepsilon_r' - 1)\,\varepsilon_o E$, where ε_o is the permittivity of free space, ε_r' is the dielectric constant of the material and E is the applied electric field. From the above two equations it is seen that a decrease in the dipole moment results in the decrease in the dielectric constant of the material as obtained experimentally (Fig. 5).

3.2. Beam Steering Property

Measurements on the beam steering property of polyanilines shows that the radiated beam direction of the polymer loaded dielectric antenna is changing continuously with the change in the applied d.c. voltage. This is indicated in Figure 6, where the "0" in the *Y*-axis represents the axial direction of the test antenna and the negative (positive) values indicate a shift in the radiated beam towards the left (right) of the antenna axis. A maximum shift of 10° is obtained for a d.c. applied voltage of 10 V for undoped polyaniline. It is followed by $HClO_4$ doped sample having a shift of 8° for an applied voltage of 5 V.

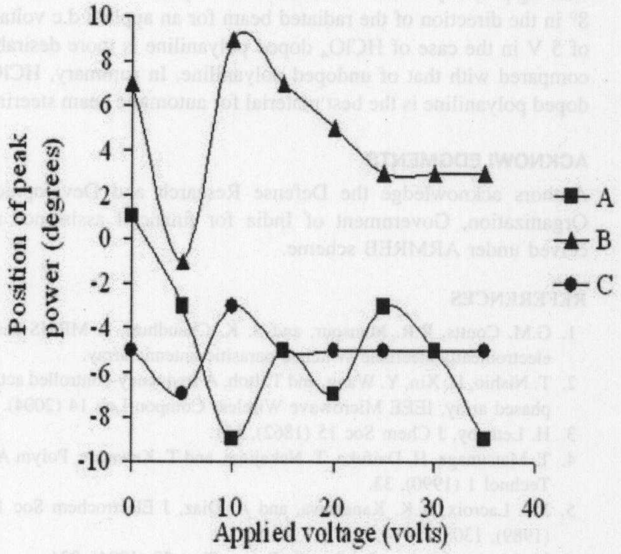

Figure 6 Variation in the position of the peak power of the radiated beam with d.c. voltage

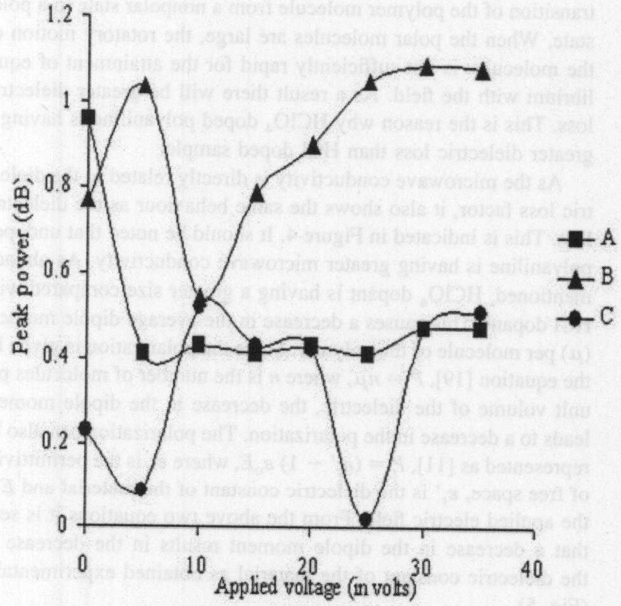

Figure 7 Variation of the peak power of the radiated beam with d.c. voltage

It is interesting to note that the peak power of the radiated beam also shows a variation with the applied voltage as indicated in Figure 7. The nature of variation however is different for $HClO_4$ doped sample compared with the other two, which means that it has something to do with the structure of the material.

4. CONCLUSIONS

Perspex rod antenna set up is an effective unit for measuring beam steering property. From an instrumentation point of view, a shift of 8° in the direction of the radiated beam for an applied d.c voltage of 5 V in the case of $HClO_4$ doped polyaniline is more desirable compared with that of undoped polyaniline. In summary, $HClO_4$ doped polyaniline is the best material for automatic beam steering.

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ANTENNA COVERING BOTH DIGITAL TELEVISION AND 2.45-GHz ISM BANDS

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ABSTRACT: *In this paper, a dual-band antenna covering both DTV and 2.45-GHz ISM bands is presented. An inset-fed monopole antenna is responsible for radiation in the DTV band. The ISM band is taken account by a strip dipole etched on backside of the monopole antenna. The antenna may also be used for dual RFID bands. Detailed design inclusive of using the inset-feed to broaden the bandwidth is discussed and experiment was done to verify the simulation.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 425–428, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23132

Key words: *digital television; dual band; antenna; ISM band*

1. INTRODUCTION

After a decade of intense research and development, digital television (DTV) has finally reached the implementation stage. Nowadays, DTV-H has already been included in a hand-held device. On PC or notebook, DTV signal is also easily accessed through a proper interface. On the other hand, wireless LAN or bluetooth system is easily connected to a PC or a mobile terminal. It is possible that more PCs or hand-held devices will own both wireless communication and audio/video entertainment features. In this paper, we present a planar antenna that can operate at both DTV and 2.45-GHz ISM bands. To our best knowledge, dual-band antennas covering these frequencies are hardly seen in the open literature. However, various designs for a single DTV or ISM band were intensively studied.

In Ref. 1, a metal-plate with three embedded slits was used as a monopole antenna to achieve a compact, yet acceptable bandwidth for DTV usage. In Ref. 2, an end-fed modified dipole was built on a FR4 substrate. In this paper, we design a monopole antenna on a FR4 substrate. The antenna can be fed by a coplanar waveguide or by a microstrip line. However, a proposed inset-feeding method reveals that the bandwidth can largely be increased if the antenna is fed by a microstrip line. Another bandwidth