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PLANAR ELECTROMAGNETIC SENSORS TO INSPECT SAXOPHONE REEDS

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Abstract: This paper details some initial work in developing a planar electromagnetic sensor for use in non-destructive evaluation (NDE) of saxophone reeds. Both theoretical and experimental approaches were undertaken. The results obtained serve as a starting point for development of a commercial sensor. This sensor has many different possible applications including quality inspection for dairy products and metal products. Conclusions are drawn from the results such as the differences observed between 'good' and 'bad' reeds. Suggestions for further research are also stated to indicate possible directions that may be taken using this research as a starting point.

Keywords: Planar mesh sensor, Saxophone reeds, Non-destructive Evaluation, Analytical model.

1 INTRODUCTION

The researches using planar magnetic sensor has demonstrated the detection of defect in the printed circuit board and the estimation of near-surface material properties of conducting and magnetic materials. The outcome of the research is very encouraging and the successful results were published in international journals [1 - 6]. The planar electromagnetic sensing technique employing radio-frequency (RF) signal is based on the interaction between the measurement signal and the material under investigation. The configuration of electromagnetic sensors used for the inspection of the quality of the saxophone reeds is of planar type. The sensor consists of two coils: one coil known as exciting coil carrying radio frequency signal generates electromagnetic field. The generated electromagnetic field interacts with the nearby materials being measured. The resultant electromagnetic field is measured by the other coil, known as pick-up coil which is placed above the exciting coil. The ratio of the voltage of the pick-up coil to the current of the exciting coil is defined as the transfer impedance. The transfer impedance is a function of many parameters such as permittivity, conductivity, permeability of the materials being measured, the lift-off, operating frequency, thickness etc. There is no direct method available to determine them separately but it is possible to evaluate the material properties with the help of some computational method. It is possible to monitor the quality of the system under test by the measurement of transfer impedance of the sensor. The advantage of this over many other testing methods is that the test material is not physically touched or altered. The method is therefore a form of Non-Destructive Evaluation (NDE) and is useful in situations where it is impractical or infeasible to destroy or damage a test sample using chemical or physical testing means. This may be because a test sample is very expensive or because every item produced must undergo the test and therefore every item must survive the test unaltered.

Another advantage of NDE is that it may be applied as a safety check to items that are already in use. As NDE does not further damage a test material it may be used to evaluate parameters such as wear and fatigue and allows pre-emptive action, such as repair or replacement, to be taken on a test subject that is about to fail.

2 APPLICATION OF THE SENSOR

2.1 SAXOPHONE REEDS

A saxophone reed as shown in Fig. 1 is a small piece of bamboo that is attached to the mouthpiece of a saxophone. When the player blows into the saxophone the reed vibrates creating sound. The reed is therefore, in part, responsible for the tone and ease of use of a saxophone. There is nothing more frustrating for a saxophone player than playing on a bad reed.

Reeds wear out after a few weeks of playing and must be replaced. The problem with reeds is that currently the quality is very variable: in a box of ten, three or four reeds are found to be 'bad' when played and are discarded. As the player pays \$10 per reed or more any improvements in quality control would be very worthwhile.

The parts of the reed that affect the quality of the reed the most are the 'vamp' and the 'tip' (See Figure 1).

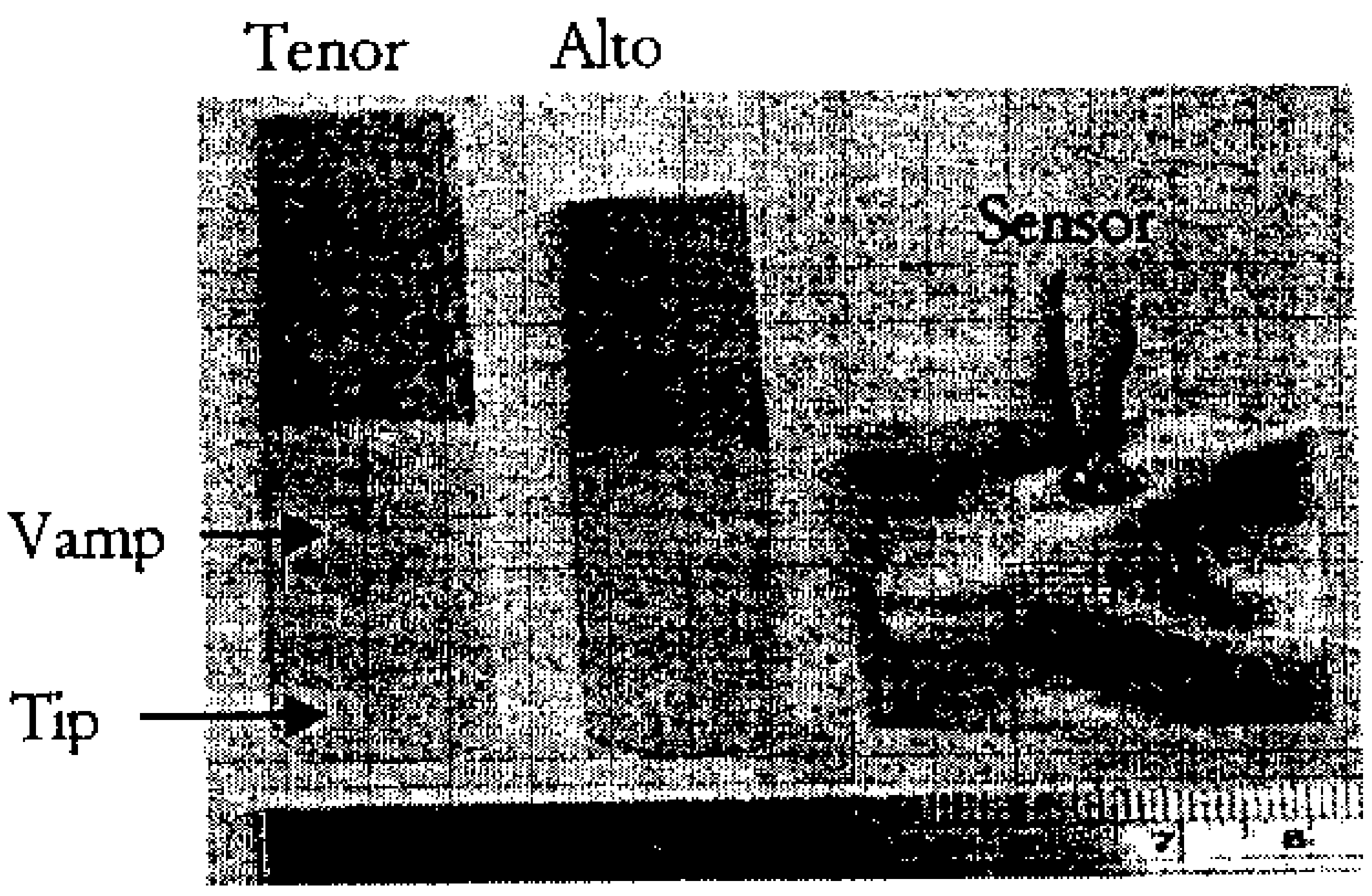

Figure 1: Tenor and Alto Saxophone Reeds, showing different sections of the reeds, and the sensor

2.2 Quantitative meaurement

The sensor is composed of a copper 'coil' that is fabricated on a polyimide film. Fabrication in this manner allows the coil to be made very precisely, as the polyimide film keeps the thin, frail coil from deforming or breaking.

The technique used to apply the coil as a sensor involves passing a known alternating electrical current through a primary exciting coil which is of mesh type. This current was a frequency sweep generated by connecting the primary coil to the transmission port of a network analyser using low loss, high frequency cables as shown in Fig. 2. The range of the frequency sweep was defined as 300 kHz –1.3 GHz. The current creates a magnetic field, the properties of which (magnitude and phase) change depending on the surrounding material's (in our case the saxophone reed's) composition and structure.

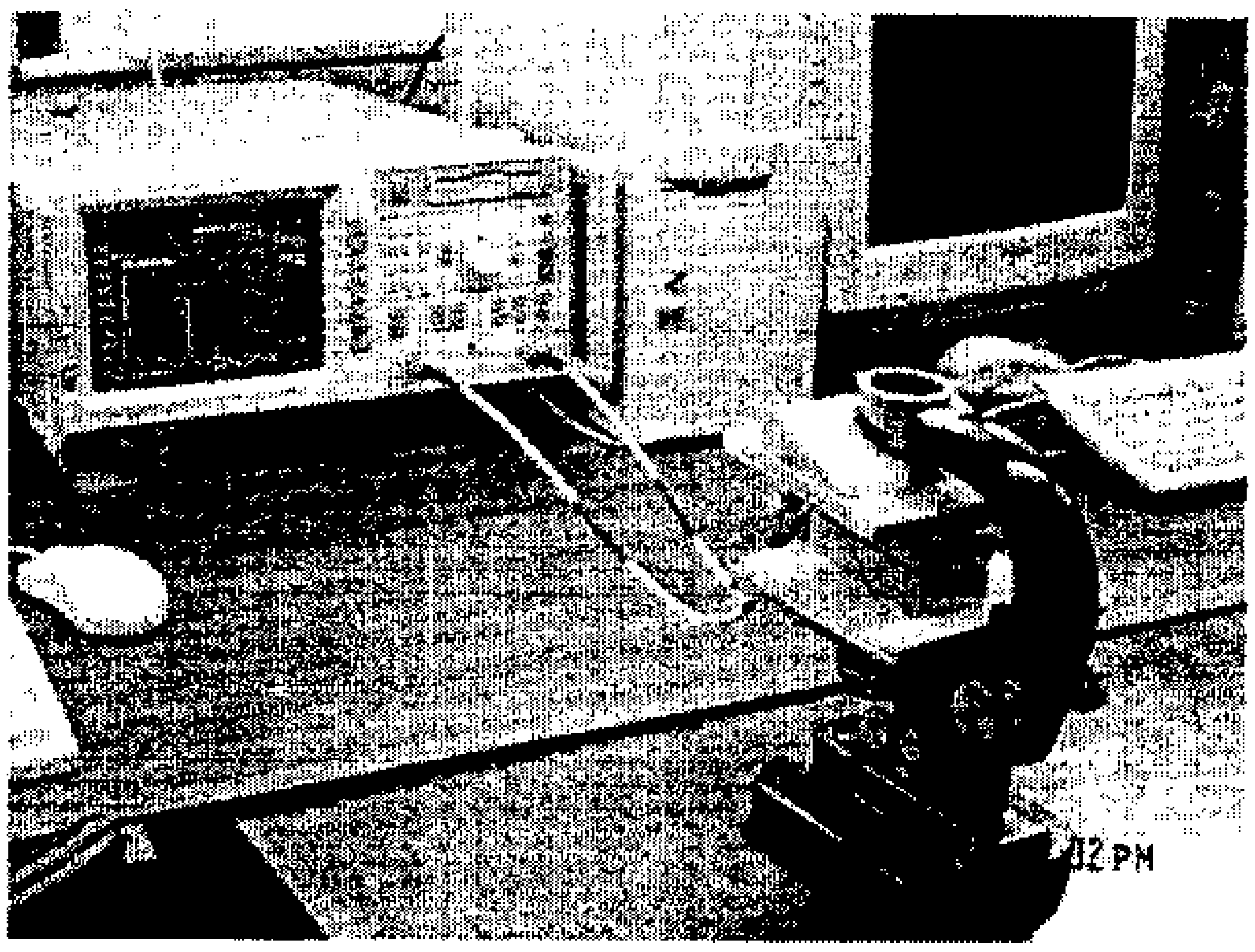

Fig. 2 The sensor, modified microscope, low loss cables and network analyser used to test the reeds

A secondary coil known as sensing coil of similar or identical construction to the primary coil (See Figure. 1) was placed near the primary coil while current is passed through the primary. The magnetic field created by the current in the primary, exciting coil induces an emf in the secondary, sensing coil. This emf was measured by connecting the secondary coil to the reception port of the network analyser. The magnitude and phase of this emf is compared to the exciting current in the primary coil. From this the network analyser calculated the transfer impedance of the sensor over the spectrum specified. This transfer impedance (both magnitude and phase) was then recorded used to predict the properties of the surrounding materials (i.e. the saxophone reed).

The sensor was placed above the reed so that it was directly above the tip and most of the vamp. The size of the gap between the sensor and the reed, called the 'lift-off' (See Figure 2) was closely controlled. Lift-off affects the results dramatically, so it was set to virtually zero by adjusting the sensor height.

2.2 PLAYING THE REEDS – QUALITATIVE MEASUREMENT

One of the authors is a very keen saxophone player, whose musical achievements include teaching the saxophone part time, playing in various musical shows, leading a Jazz Quintet, playing in the Manawatu Jazz Club Big Band and also in the New Zealand National Youth Jazz Band. This experience created the initial interest in developing the sensor for use on saxophone reeds.

The experience also gives the author a good idea of what a 'good' and 'bad' reed sounds and 'feels' like when played. This allowed the reeds to be tested qualitatively by playing them for approximately ten minutes to gain an idea of how the reed performed in specific areas such as tone quality. This assessment was done before quantitatively testing the reeds so as not to make the qualitative test of playing a reed fit the quantitative results obtained from the sensor i.e. avoiding bias.

Reeds were rated on the following parameters: ease of attack, ease of sustain and tone quality in the low, mid and high ranges of the instrument as well as a score for volume. These parameters were then averaged to get the overall score.

2.3 THEORETICAL MODEL

The analytical model of the sensor of the Fig. 1 has been carried out assuming the sensor is placed on the reed under test as shown in Fig. 2 and the transfer impedance of the sensor as a function of the permittivity and other parameters such as permeability, conductivity etc. of the reed has been calculated. The detailed description of the development of analytical model has been described in

[7, 8]. Figs. 3a and b show the variation of the resistive part and the reactive part of the transfer impedance as a function of the relative permittivity of the product at an operating frequency of 500 MHz. It is seen that the transfer impedance changes appreciably with the relative permittivity and the magnitude of the transfer impedance can very well be used to predict the permittivity by some computational technique. Figs. 4a and b show the variation of the resistive part and the reactive part of the transfer impedance as a function of the relative permittivity of the product at an operating frequency of 1 GHz. It is seen that the rate of change of both the real and imaginary part of the transfer impedance is much higher compared to that of frequency at 500 MHz.

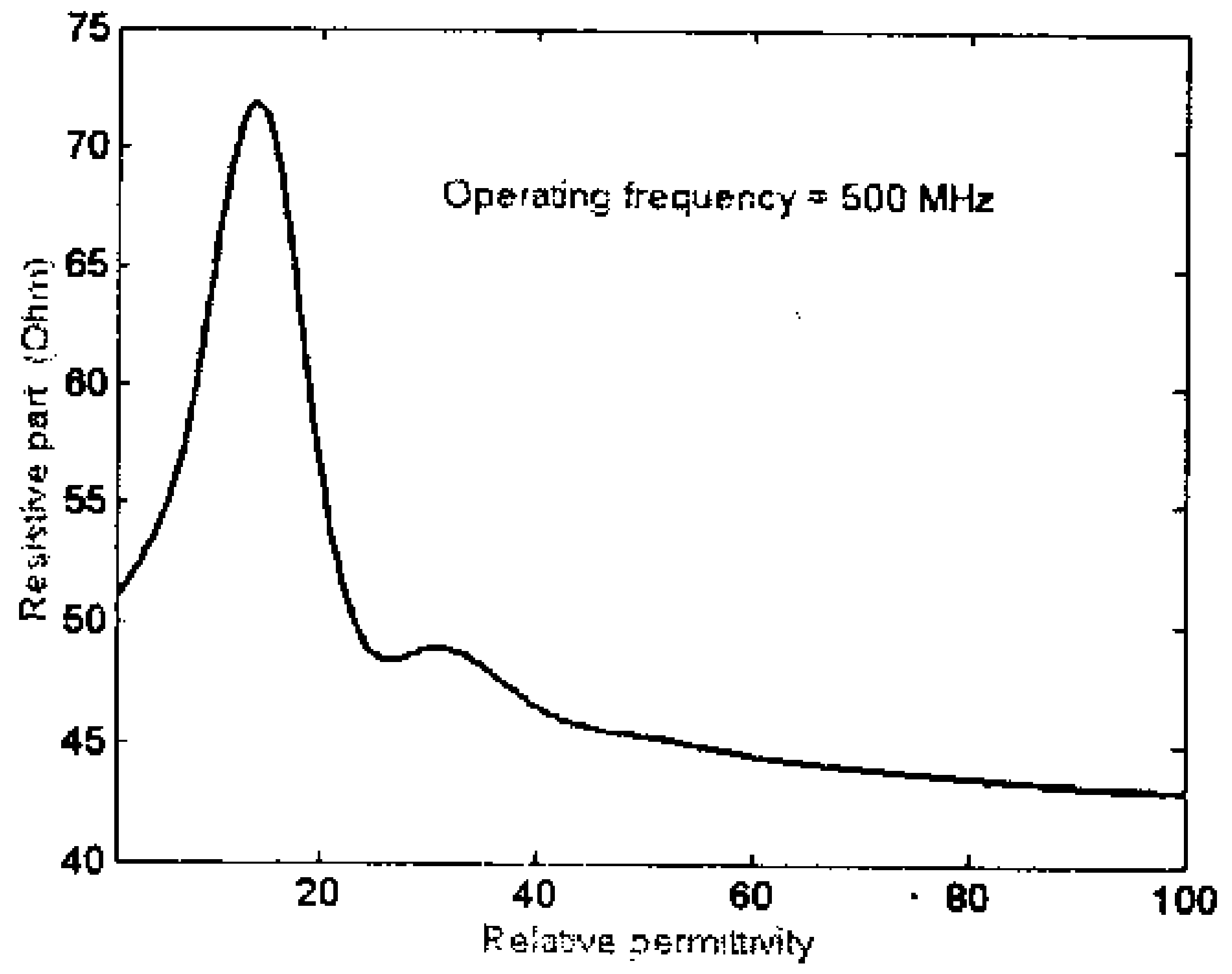

Fig. 3a Variation of resistive part of transfer impedance with permttivity

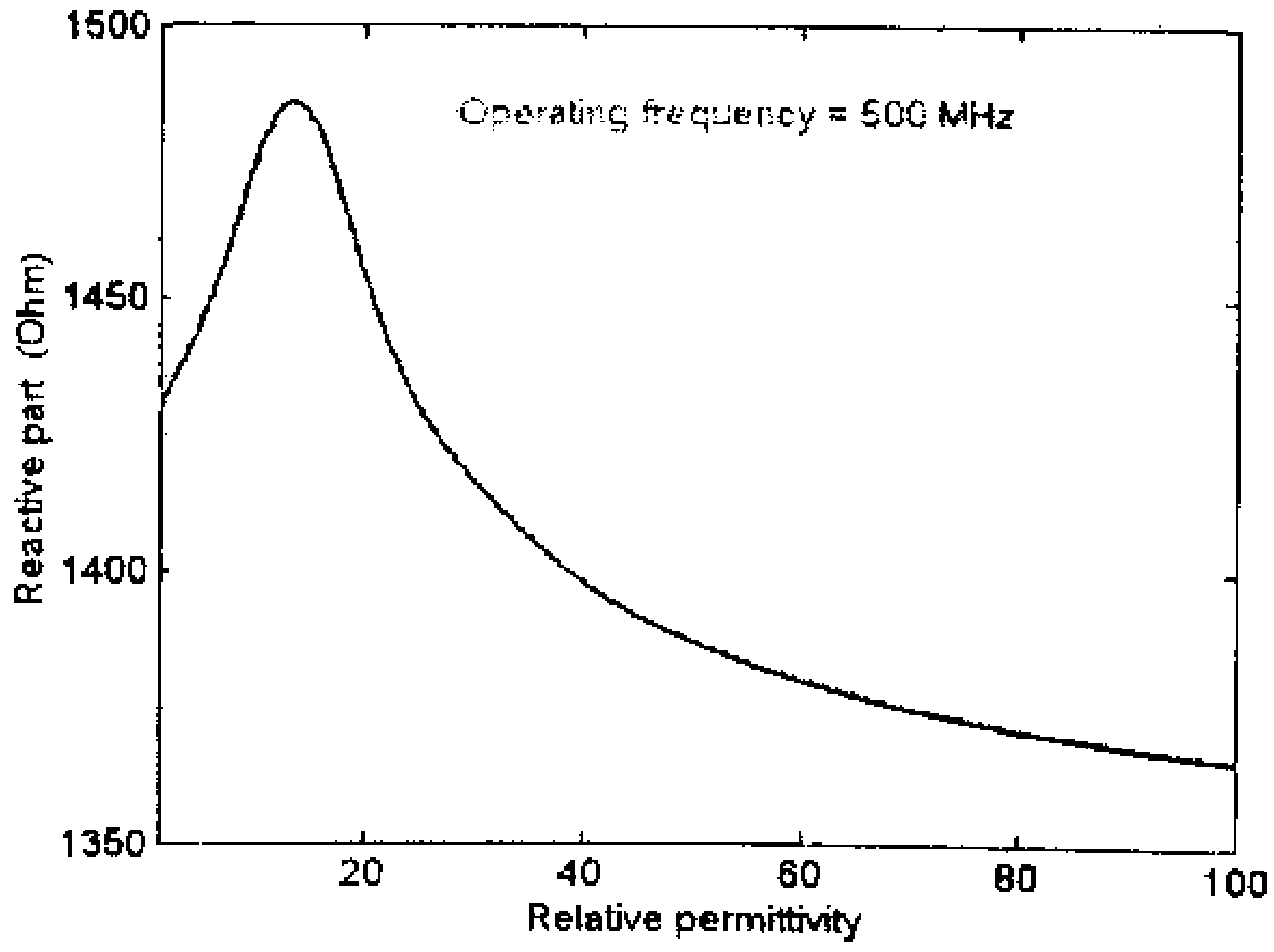

Fig. 3b Variation of reactive part of transfer impedance with permttivity

So the selection of frequency is very important to deal with dielectric material like the reed. Usually an operating frequency of higher than 500 MHz is used for this purpose.

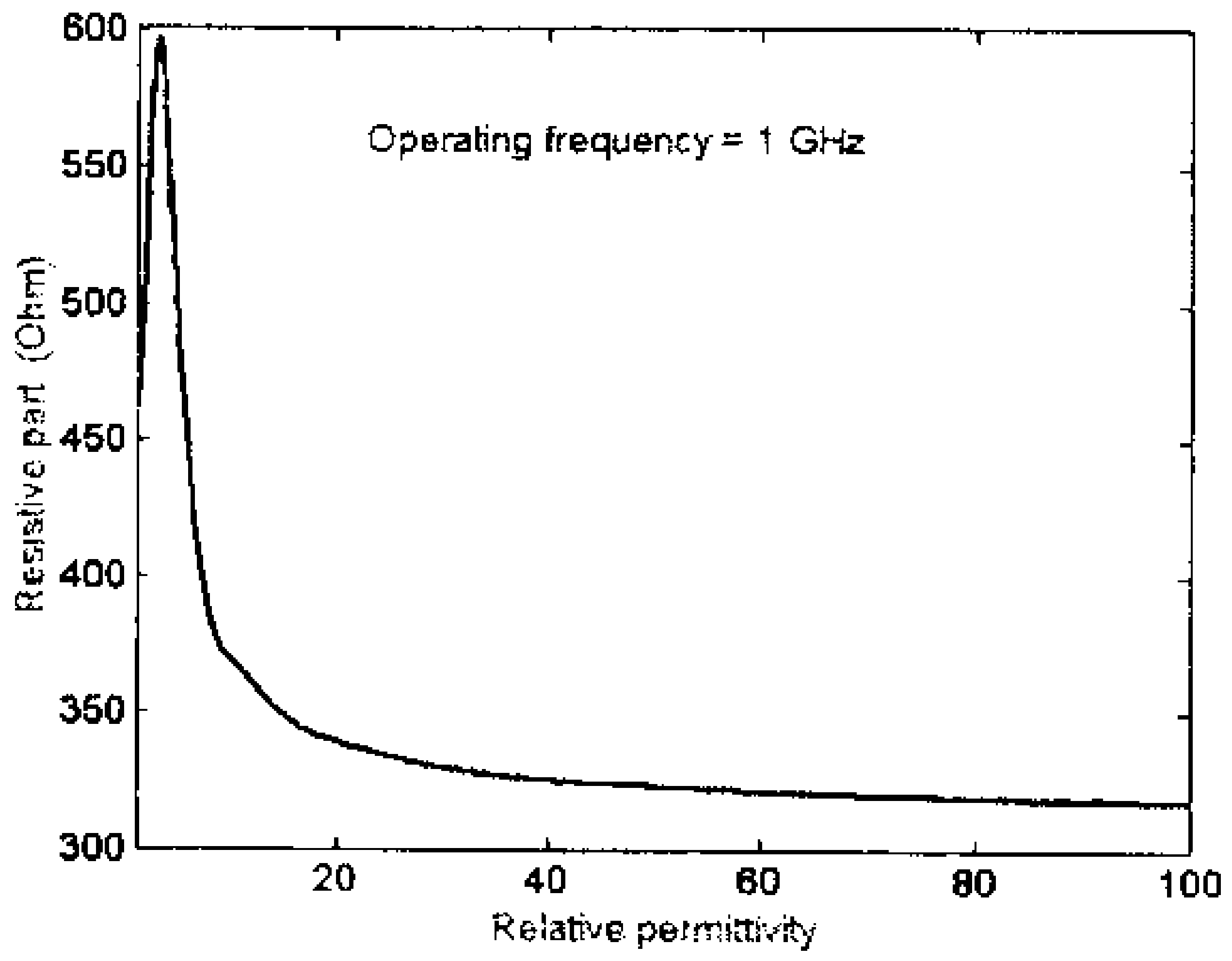

Fig. 4a Variation of resistive part of transfer impedance with permttivity

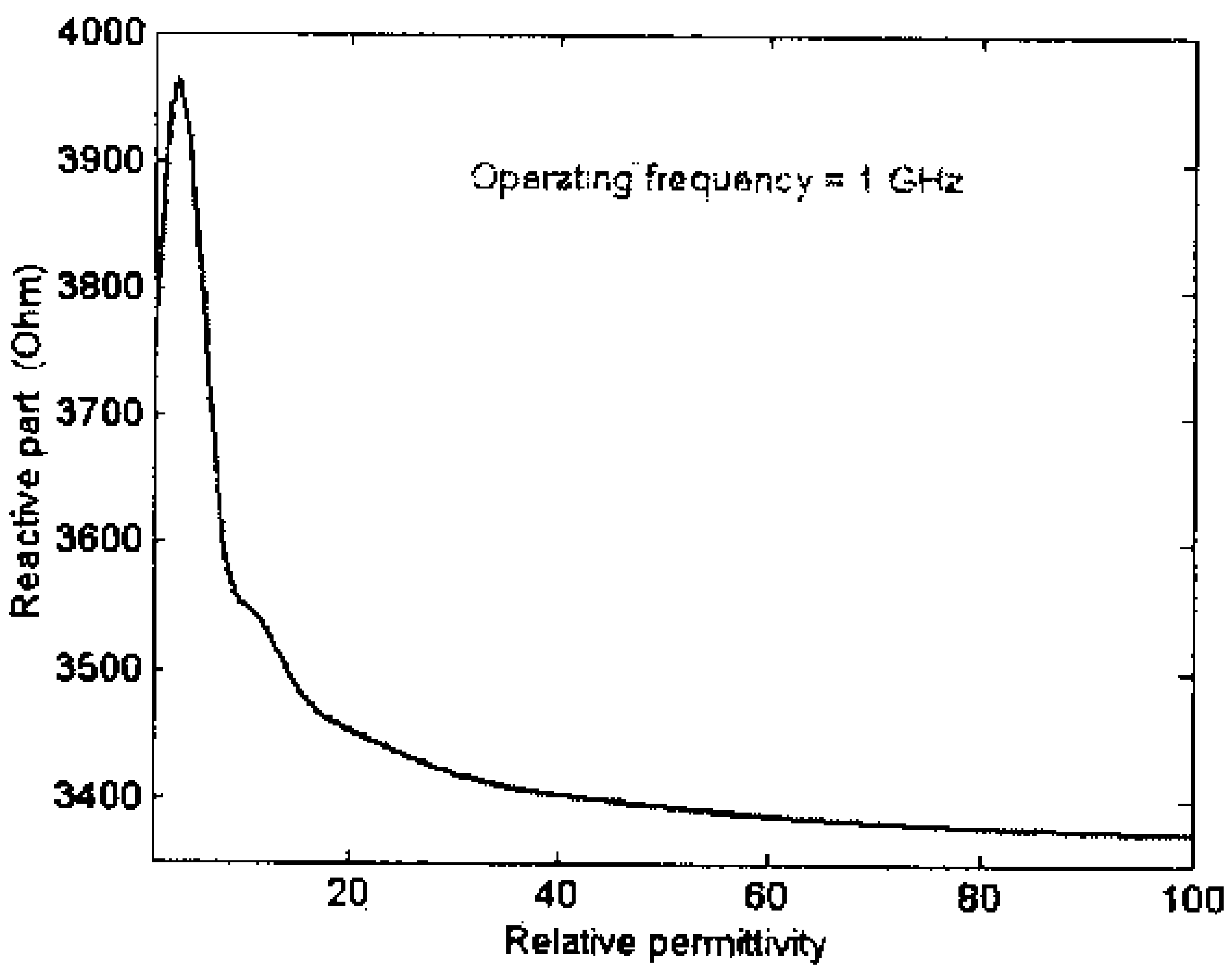

Fig. 4b Variation of reactive part of transfer impedance with permttivity

It is seen from Figs. 3 and 4, that the reed behaves as a resonant circuit and gives a peak at a resonant frequency. In the analytical model he permittivity is assumed a constant parameter but in practice the permittivity varies with the operating frequency. The experimental results thus show many peaks when the magnitudes are plotted as a function of frequency.

3 EXPERIMENTAL RESULTS

Both qualitative (by playing reeds and scoring them out of ten) and quantitative (by measuring the response of the sensor) results were obtained. These results are shown in Table 1 and Figs. 5 and 6.

Table 1. Saxophone reed quality

Reed #	Alto/ Tenor	Played Much?	Strength	Overall Quality
1	**Tenor**	**Old**	**2.5**	**6**
2	**Tenor**	**Old**	**2.5**	**6**
3	Tenor	Mid	2.5	9
4	**Tenor**	**Mid**	**2.5**	**4**
5	Tenor	New	2.5	9
11	Tenor	New	2.5	9
12	Tenor	New	2.5	8
13	Tenor	New	2.5	8

It should be noted that the sample of reeds tested have exactly the same response as each other except that reed 1 differs from the other reeds at one point in the magnitude plot, near 150 Mhz and, more importantly, differences at the 579 MHz in the phase plot may be observed (Figs. 5, 6). This frequency corresponds to an impedance magnitude peak (local maximum) for all reeds. At this point the reeds give different responses and may be separated into two distinct groups based on their phase response.

Bearing this grouping in mind, all the members of the group with the larger phase angle at 579 MHz have been bolded in the qualitative test results (Table 1). All these bolded entries scored lower and may be said to be the 'bad reeds', while the members of the other group all obtained very high overall scores.

Due to the small sample size analysed to this level, the results are promising, but not conclusive.

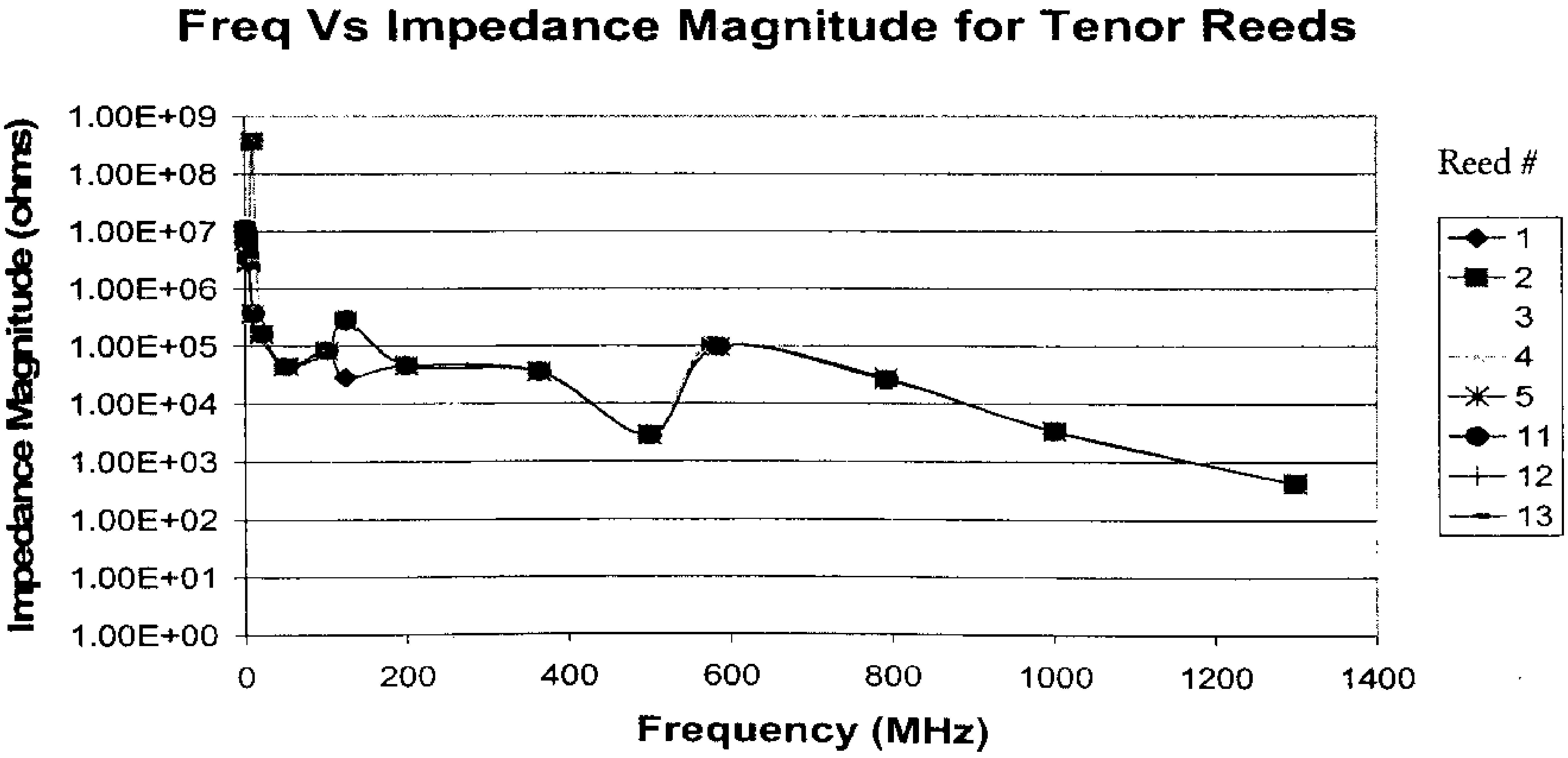

Fig. 5: Magnitude Response of Sensor

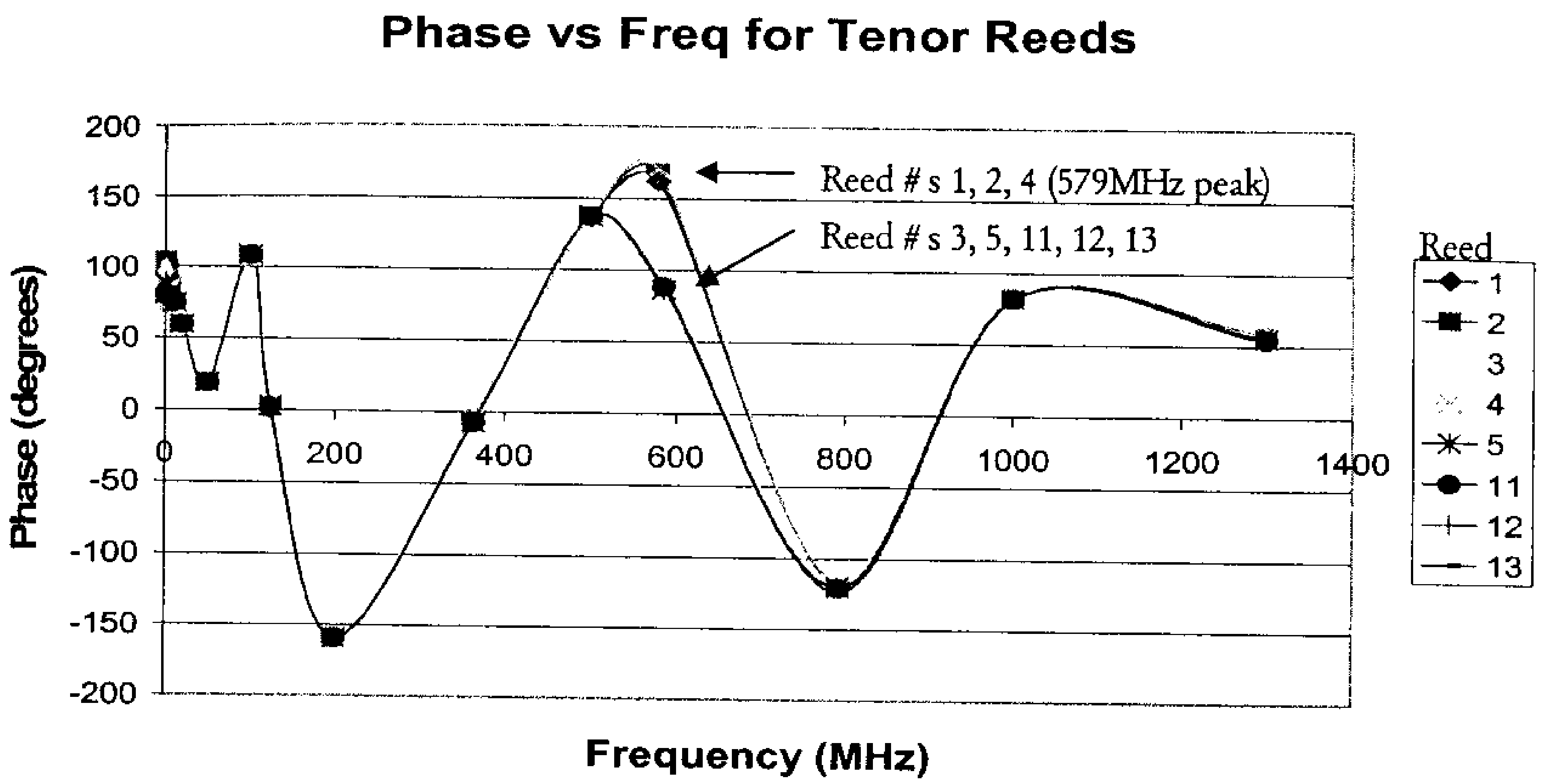

Fig. 6: Phase Response of Sensor

4. CONCLUSIONS

Non-destructive evaluation (NDE) is a technique that may be applied to many different areas. This paper looks as the specific case of saxophone reeds and begins to develop a sensor for this purpose.

Initial results for quality inspection of saxophone reeds are promising. There appears to be a measurable difference given by the sensor between 'good' and 'bad reeds. A larger sample size must be taken to confirm this hypothesis, which is planned to be done now.

Further work must be completed to develop a theoretical model that adequately describes the sensor and reed. Initial work has involved the development of a 2-dimensional analytical model. Using the finite element method a 3-dimensional model is being planned to be developed taking into account all desirable factors along with the proper shape of the reed.

Further research would be to develop this sensor to a commercially viable product may be undertaken, using this paper as a starting point. The author has also undertaken considerable research into applying the sensor to other situations such as metallic and dielectric substances, with both theoretical and experimental results being available.

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