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THE EMFi MATERIAL AND THEIR USE

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ABSTRACT

ElectroMechanical Film (EMFi) is a thin, plastic material that can be utilized as a sensor and actuator. EMFi is quite new material in the field of ultrasonics and has favorable properties like good matching to air in comparison to present transducer materials. The device detect, if there is an object in front of the transducer.

KEYWORDS: sensor, ultrasonic, EMFi

1. Introduction

The ElectroMechanical Film (EMFi) is a thin, cellular, biaxially oriented polypropylene film that can be used as an electret-type active material. It is capable of measuring pressure and force changes offering large application potential in different field of technology including different sensor and actuators [1]. High sensitivity, light weight and relatively low cost are the main advantages of EMFi. It is thin and easy to cut to almost any shape and size. So, it can be easily integrated as a functional part in different mechanical structures. The film can be also laminated between plastic films to protect the material mechanically in harsh environment. This construction also provides a good protection against water and humidity. The base material is low-priced polypropylene, which makes EMFi-sensor competitive also in large area applications like in surveillance sensor systems installed on the floor [2]. EMFi based guitar microphones and special sensors for health care applications are commercially available[3,4]. Various EMFi actuators have been developed and tested for audio and active noise cancellation applications[5].

2. Electromechanical film

The EMFi is an electret film with cellular internal structure , which is created by biaxially orienting a specially fabricated polymer perform. Having a special voided internal structure and high resistivity, it is capable of storing large permanent charge. The charge is injected during manufacturing by a corona method using a high electric field. The material shows a strong quasi-piezoelectric response when compressed . The sensitivity coefficient of EMFi is typically d_e=25-100 pCN^{-1}[4].

3. Sensor operation

Operating in a reciprocal fashion, changes in the thickness of the EMFi sensor generate a corresponding charge and hence, voltage to appear on the electrodes. The transducer behaves like an "active" capacitor, consequently, the loading of the signal by the input impedance of the measuring device must be considered. Due to the thinness of the films, the associated capacitance can be sufficient to give adequate low frequency response to a standard 1MΩ load but the use of an X 10 probe will extend the low frequency range by a decade. For extremely low force change levels, some buffering may be desirable. For the majority of analysis work, this is unnecessary and the film can feed directly to the instrument. Again, the low mass contributed by the transducer is of major importance, as well as its non-resonate behaviour. Frequency response is inherently flat to over 20 MHz with only the RC roll off at low frequencies distorting the profile. Though it responds to thickness change rather than stain, low signal levels may be generated by low frequency flexing, so a distinction must be made between the frequency response of the film for changes in its primary parameter and its relative behaviour compared with, say piezoelectric sensors. The sensor has a flat response over a very wide frequency range, with resonant frequency points well above 20 KHz.

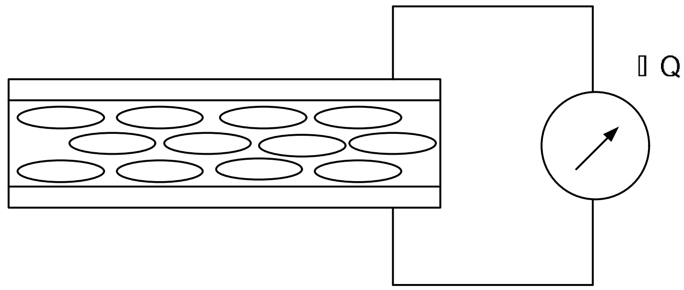

Fig. 1 Sensor operation

Table 1 Other Specifications

Property	Symbol	Value	Unit	Tolerance	Conditions
Storage temperature	T_s	From -40 to +50	^{0}C		
Operating temperature[1]	T_r	From -20 to+50	^{0}C		
Thickness	D	70	µm	±5%	
Sensitivity[2]	Sq	25-250	pC/N	±20%	Normal force
Youngs modulus, TD		0,5	Mpa	±50%	
Operating force range	P	>100	N/cm^2		

1. Loss of sensitivity is <20% after the following temperature cycles:
a) 11 hours at -20^{0}C, 11hours at +70^{0}C, 1hour at +20^{0}C,28cycles.
b) 1 hour at -20^{0}C, 1hour at 70^{0}C, 10 cycles.
2. sensitivity depends on the pre-aging. Max sensitivity available is to about 250 pC/N.

The operation of the film has been modeled in details based on the structure of the material and its internal charge distribution.

EMFi material behaves like a capacitive generator type sensor. The charge signal ΔQ at the electrodes is proportional to the dynamic force ΔF exerted to on the film surface. The signal voltage across the sensor film is

$$\Delta V = \frac{\Delta Q}{C_S} = \frac{d_e \Delta F}{C_S} \qquad (1)$$

Where d_e is the sensitivity coefficient corresponding piezoelectric coefficient in a piezoelectric material

$$d_e = \frac{\Delta\sigma}{\Delta p} = \frac{\Delta Q}{\Delta F} \qquad (2)$$

And C_s is the capacitance of the sensor film. Δσ is the change of the change density on the lectrodes and $\Delta p = \Delta F / A$ is the amplitude of the dynamic pressure within the area A where the force is acting.

The reciprocity of the electromechanical coefficient can be utilized to calculate the thickness change Δs of the film in the actuator mode

$$\Delta s = d_e \Delta V \qquad (3)$$

Where ΔV is the external driving voltage, and d_e is in this case typically 25-100m^{-12}V^{-1}.

4. Ultrasonic radar

The ultrasonic radar is based on EMFi. The radar detects, if there is an object in front of the device. The planned range of the device was a few meters indoors.

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The radar has been implemented at the Institute of Measurement and Information Technology in Tampere under the supervision of Mr. Jukka Lekkala.

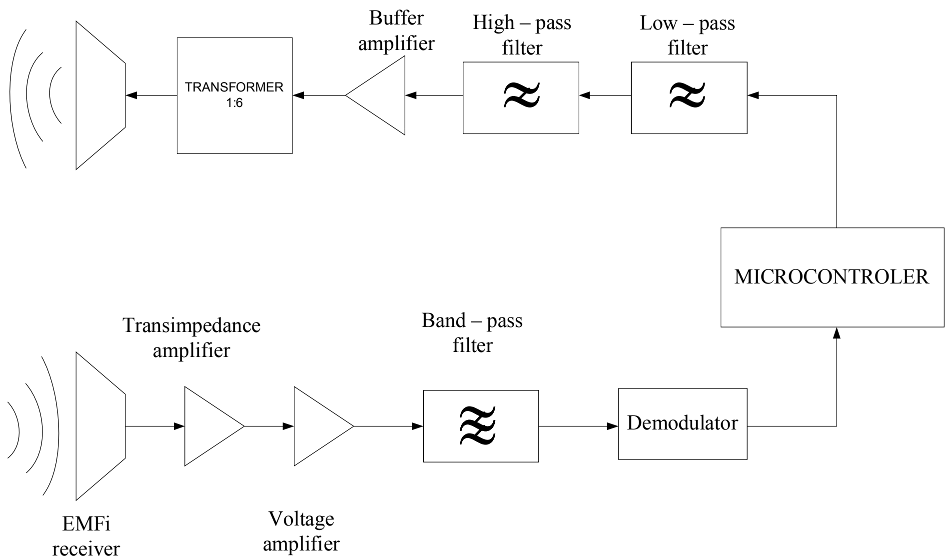

Fig. 2 Block diagram of the ultrasonic radar

Ultrasonic EMFi transducers and a preamplifier were built as a separate unit. All other electronics like power source, analog signal processing and microcontroller were placed to a main unit. The block diagram of the constructed radar system is shown in Fig. 2. The built device is powered by two 9V alkaline batteries. The operation of the radar is quite conventional.

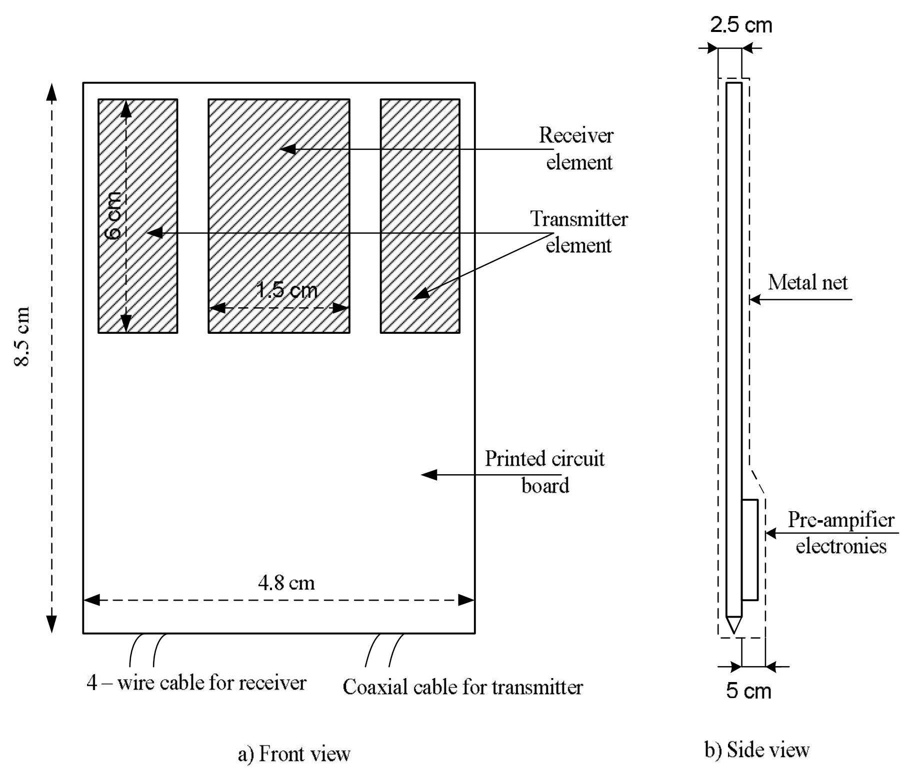

Fig. 3 EMFi transducer built on PCB. Two EMFi transmitter elements on the edges of the PCB were used to send ultrasound. The one in the middle acts as a receiver.

The constructed device sends ultrasonic bursts and then detects, whether there are echoes present within a certain time window. At the beginning of a detection cycle, the microcontroller produces a series of excitation pulses at frequency of 34 KHz.This signal is filtered and then fed to a buffer amplifier stage that is able to drive a transformer. The ferrite core tep-up transformer is used to increase the driving voltage level of the EMFi transmitter element up to $122V_{pp}$.

The EMFi receiver element is used to convert acoustic echo back into electrical signal. The received signal is amplified and band-pass filtered to improve signal to noise ratio. AM demodulator is used to detect received burst. The demodulator produces a positive voltage pulse and the height of the pulse is proportional to average signal level of the incident ultrasonic burst. If the level of the pulse crosses a pre-set threshold level, the flight time of the ultrasound burst is calculated. This is realized on a comparator in the microcontroller unit. If the burst arrives in preset time window an object is assumed to be present.The transducer unit includes thin EMFi transmitter elements, receiver element and the first two amplifier stages of the receiver circuitry. Three similar EMFi elements were clued on a printed circuit board. This procedure supports ductile EMFi elements and helps to create firm reliable contacts. The capacitance of one element is 0,4 nF. As the preamplifier is located near to EMFi elements, it is possible to keep transmission lines short and maintain good electrical shielding. This is important because EMFi receiver element is prone to electrical interference.

The receiver element was placed between the two transmitter elements. Two separate transmitter elements increase the output signal but make directivity pattern of the transmitter a bit complex. This kind of transducer configuration is symmetrical and still relatively easily built.

5. Conclusion

The measurements done in the above laboratory have concluded that the area normal to incoming ultrasound and the reflection ratio between air and the target material determines the amplitude of the echo. The device can see small objects like coin or aluminum perceive at distances shorter than70 cm.

The piece of aluminum was detected at least within a range of 2m. The results show that the EMFi material provides interesting possibilities to integrate sensors and acuators in monitoring and user interface applications.

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