Self-Adaptive Flexible Antenna Array System

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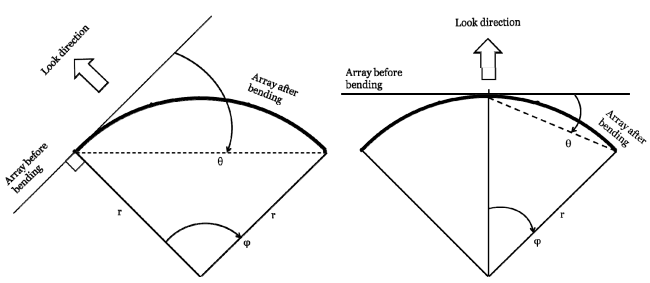
***Abstract*— In the last decade self-adaptive and reconfigurable antenna arrays gained a lot of interest, and the concept of converting a simple antenna element or antenna array into a smart system was one of the research growing areas.**

I. Introduction

In this paper a self-adaptive antenna array system is proposed in which the system sense the antenna array surface bending and change the radiation pattern accordingly to mitigate the bending effect. The control circuit used is in the system is based on ATMEL ATMEGA 2560 chip which programmed to work as an interface between the flex sensor and the phase shifters at the input of each antenna element. To construct the proposed antenna array four Coplanar Folded Slot Antenna (CFSA) [1, 2] elements are used; microstrip antenna elements can be integrated with this system as well.

The system can be configured to mitigate the bending effect for different bending configurations; here the system is set to compensate the circular edge bending configuration (Fig. 1a) which is more complicated situation compared to the simple circular center bending configuration as in Fig. 1b. The antenna array bending equations are derived using some geometric analysis and antenna arrays fundamental equations [3] to relate the bending angle and the phase difference required between the antenna array elements to restore the beam to the look direction. These bending calculations did not take the effect of inter-element mutual coupling in the antenna array into account; therefore an error of few degrees can be expected in the measurement as it will be shown in the results.



(a) (b)

Fig. 1. Two bending configurations, a) circular edge bending, and b) circular center bending

In the next three sections the system components will be described in more details.

II. Phase Shifters

The analog phase shifters used in the system produces a continuous phase shift based on the input control voltage applied. Normally in analog phase shifter, reverse biased varactor diodes are used to achieve the desired phase shift between the input and output. The used chip HMC929LP4E is an analog phase shifter works between 4 GHz and 8 GHz with insertion loss of 2.8 to 4dB and typical phase error of ±5˚ [4]. A suitable circuit board was designed specifically for the 4 x 4mm chip and then each of the four phase shifters is soldered on a circuit board. The performance of the phase shifters is characterized as in Fig. 2 and the measurement showed similar results for all the four circuits with ±0.1 dB insertion loss tolerance.

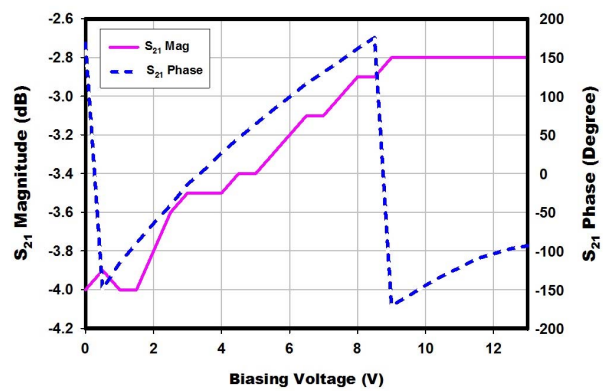


Fig. 2. Measured S_{21} magnitude and phase of the used phase shifters

III. Power Divider

A 1 x 4 microstrip power divider is designed and simulated where all of the four output ports have identical insertion loss of -6.02 dB with in the frequency range of 5 GHz to 6.5 GHz. Then the design is fabricated to find almost -6.5 dB insertion loss from all of the output ports which can be due to losses caused by the connectors or microstrip circuit dissipation. On

the other hand the phase for all four ports is found to be the same.

IV. Microcontroller Circuit

First, the microcontroller chip is used to measures the flex angle of the sensor which works as a variable resistor and change its impedance value based on the bending angle. Then based on a programmed bending equation the required amount of phase shift needed for each antenna element is computed. In order to compensate this bending effect four phase shifting circuits are attached to the input of each antenna element and the required control voltage to each phase shifter is calculated using a predefined curve fitted equation. Since the phase shifting chips used are analog devices -with 0 to 13V control range- while the microcontroller chip has a digital output, the microcontroller and the phase shifters have to communicate through a Digital to Analog Converter (DAC) chip. To achieve an accurate and fine voltage control a 12-bit DAC chip is used with 0 to 2.5V output range, meanwhile the phase shifters require 0 to 13V control voltage. Therefore an array of four operational amplifiers (op-amps) with 5.1 gain factor each is used to rise up the controlling voltage to the required range. In Fig. 3 a block diagram for the microcontroller circuit showing all the control circuit components is depicted.

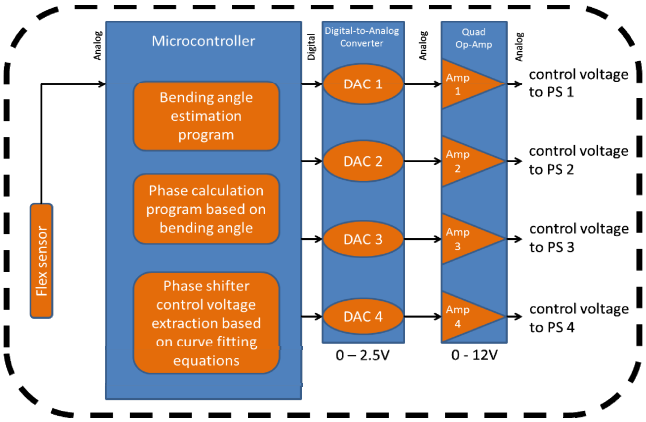


Fig. 3. Block diagram of the sensor connected to the control circuit

V. Measurement

In order to investigate the feasibility and the performance of the proposed system, the whole system is constructed and the antenna array radiation pattern is measured for edge bending configuration. In this example an array of about 30 degrees bending angle was chosen; in the first measurement the radiation pattern was measured without connecting the control circuit as presented in Fig. 4. Then for the second measurement the control circuit is connected to the antenna array and the phase shifters in order to rectify the bending effect. Fig. 4 shows the radiation pattern after restoring the main beam in the desired/ look direction (at zero degrees). A few degrees of angle error was noticed in the rectified pattern (the sold curve in Fig. 4), as described before that could be due to neglecting the mutual coupling effect between the array elements.

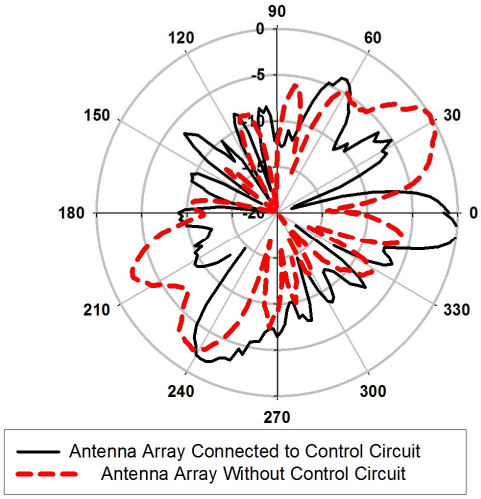


Fig. 4. Antenna array measured radiation pattern when the control circuit is connected/ disconnected.

VI. Conclusion

In this work a new self-adaptive antenna array system is proposed showing the ability of the system (antenna array and control circuit) to control the phase shift at the input of each element to minimize the antenna array bending effect.

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