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Research Article

A Novel Mathematical Computing Simulation Methodology for Acoustic Phased Array Antenna of SODAR System

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Abstract

Wind profile measurement in the earth's lower atmosphere using remote sensing technology has play most important role in emerging trends. SODAR, a remote sensing system which is using to measure the turbulence in the wind, through transmitting an acoustic pulse in to the earth's atmosphere and receiving the scattered signal. Among the various remote sensing techniques, to obtaining wind patterns in the earth's lower atmospheric layer, acoustic wind profiler is the best technique when compare to other techniques. Here in this paper, a phased array antenna has been developed for the atmospheric wind measurements. The system has the capability to remotely measure atmospheric horizontal and vertical winds up-to 1000 meters within the earth's atmospheric boundary layer. This phased antenna has designed with 8 x 8 array tweeters to obtain accurate side lobes of the transmitted signal. The Intend of this paper is to compute the mathematical algorithms of the 8 x 8 and 5 x 5 acoustic phased array antenna using a scientific software, MATALB. MATLAB is a numerical computing software with rich in displaying graphical representations. When observed the result from the traditional computing techniques and this novel computing methodologies, this novel computing has reached the real-time values measured by the system.

Keywords: *Wind profile, Atmosphere, SODAR, Array, Antenna, Acoustic, Pulse, Computing, Turbulence, MATLAB.*

1. Introduction

SODAR (SOund Detection And Ranging) is a systems which is used to measure wind speed at various heights above the ground level and also capable of estimating the thermodynamic structure of the lower layer of the atmosphere. The system uses acoustic signal for its operation. Typically here we uses the acoustic pulse of 2 Kilo Hertz frequency with 2 mille second's duration. A wind profiler will use these acoustic waves to measure wind speed at various heights. When a pulse of 2 Kilo Hertz sound is radiated into the atmosphere, it interacts with these eddies and the energy in the sound pulse is scattered in all directions.

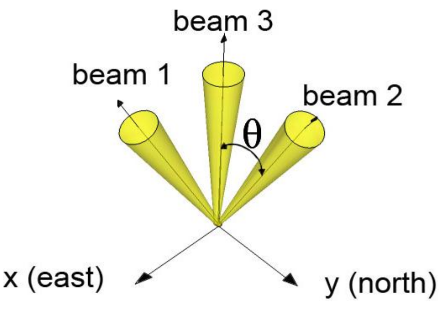

Figure 1: Anatomy of sodar system signal direction.

The Doppler Shift produced in the backscattered signals due to the Movement of these eddies is measured and computations are made to derive radial winds that are then used to give horizontal and vertical winds. Radiating of acoustic pulses has employed with different techniques. SODAR system has broadly categorized into two types depending on the technique involved in the transmitting and receiving of the acoustic signal.

A mono-static SODAR system, which uses the single antenna for transmitting and receiving the acoustic pulses, while a bi-static system uses separate antennas. The basic difference between these antenna systems are, which determines whether atmospheric scattering is by temperature fluctuations, or by both temperature and wind velocity fluctuations. If it is due to both temperature and wind velocity fluctuations, then it is possible to measure with bi-static SODAR system only. In mono-static system can observe the scattering, if it is only with the effect of temperature fluctuations. Here in this paper, we have designed a uniform planar phased array antenna with high-efficient piezoelectric tweeters. The elements at each corner of the planar phased array antenna has removed to optimize the side-lobe and the beam width of the main-lobe. To design the antenna its necessity to follow the various antenna techniques to get better optimization of the side-lobe and also mail-lobe. All these mathematical algorithms has developed with MATLAB software and according to the results, an antenna has developed and compared with the real time values obtained through this

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8x8 planar phased array antenna. Here in this paper mostly are going to describe the developing of the algorithms in MATLAB software and results are explained through the simulated graphs of the MATLAB.

Figure 2: Sodar antenna at dept. of systems design, Andhra university. Sponsored by UGC and ISRO

2. Algorithm Development Methodologies

The Development which is carried out in this paper has categorized in to five sections and experimentally proved up-to three sections remaining two sections are discussed further. These categories are 1. Speakers and Microphones. 2. Horns. 3. Phased array Frequency range. 4. Dish Design. 5. Designing for Absorption and background noise.

Speakers & Microphones

The choice for Speakers to designing the array antenna are two types. We can use piezoelectric horn tweeters or high efficiency coil horn. Here in this paper designed an array antenna with piezoelectric horn tweeters. The advantage of piezoelectric array antenna is well suitable for beam steering concept which is not possible with dish type antenna. The sensitivity of the particular tweeter intensity level L can be calculated with Equation.1, generally measured at a distance of 1 meter for 1 watt input electrical power.

$$L = 10 \log_{10} \frac{I}{10^{-12} W m^{-2}}$$

Equation.1: Sensitivity of the Individual tweeter.

The conversion to acoustic power is considered as an electrical loosely process and this is equivalent to a resistance of the tweeter. The power output is directly proportional to square of the V_{rms} and also the intensity is inversely proportional to the square of the distance, so the intensity produced at a distance (z) will calculate through the Equation.2.

$$I_Z = 0.0025 \left[\frac{V_{rms}}{2.83Z}\right]^2 = 0.3\, Z^{-2}\, m\, W m^{-2}$$

Equation.2: Intensity at Distance of a tweeter.

The purpose of modeling performance a good fit to the angular patterns has obtained using $I_{MAX}\mathrm{Cos}^4\theta$ with I_{MAX} =0.31. And 3.1 Wm^{-2} for 35 V_{rms} at 1m and for frequency $f_{t.}$ at 1.5, 2, 2.25 and 2.5 kilo Hertz. From the experimental measurements shows that tweeters impedance at f = 2 kilo Hertz is about 125 ohms and is equivalent to a 0.06 microfarad capacitance in parallel with at 1 k ohm resistor, which shows that the electrical power dissipated from 35 V_{rms} input is 0.06 watt. Therefore the electric- acoustic power conversion efficiency is around 50% at 1 kilo hertz and in and around 100% at 2 kilo Hertz.

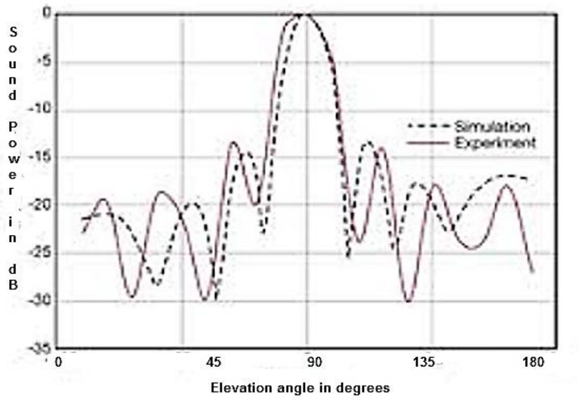

Figure 3: Radiation pattern of the uniform 8 x 8 tweeter array antenna at two frequency steps 2 kHz and 2.1 kHz.

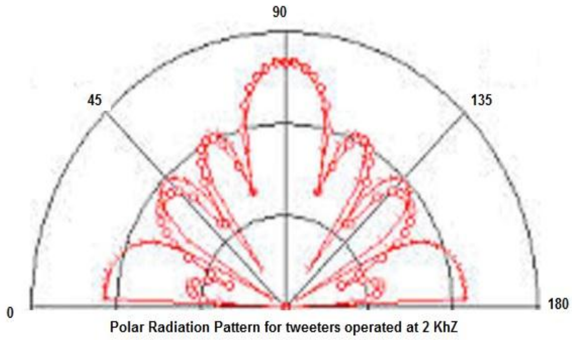

Figure.4: Normalized polar Radiation pattern of the uniform 8 x 8 tweeter array antenna at three frequency steps 2 kHz.

Horns

All these tweeters have an acoustic horn connected through the driver element to the atmosphere. These acoustic horn will be act as an impedance- matching element for the small displacement. Horns generally consists diaphragm area larger than the throat area. The ratio between diaphragm and throat area will be known as compression ratio of the horn. If this compression ratio is 2:1, then the frequency ranges will be considered as moderate, if it is 10:1 will be considered as high frequency range tweeters. Here we considered and experimentally observed that the length of the horn should be about the longest wavelength (λ_L) and the circumference of mouth of the horn should be equal or greater than the wavelength (λ_L). Through our experiments, have conclude that for a 2 kilo Hertz system the horn should have about 170 mm length and 54 mm diameter.

Phased array frequency range

Actually the beam polar pattern is considered as the product of the tweeter polar pattern and the array pattern. If, want to change the individual tweeter pattern can change by changing the frequency of the individual tweeter. Figure.5 shows the measured pattern for a Ahuja at 4.5 and 4.7 kilo Hertz. It is proved that the array pattern will dominate over the small changes in the individual tweeter pattern. The first minimum from an array consisting of M x M tweeters separated by distance d is given by Equation.4. Therefore the large array the beam width is inversely proportional to frequency of a tweeter. The side lobe zenith angles $\boldsymbol{\theta}_{\mathrm{L}}$ on the either side of the main lobe, can be calculated through Equation.3.

$$\sin\theta_L \;=\; \left(\frac{3C}{4f_T d}\right)\left(\frac{5C}{4f_T d}\right)$$

Equation.3: Zenith angles $\boldsymbol{\theta}_{\mathrm{L}}$ on the either side of the main lobe

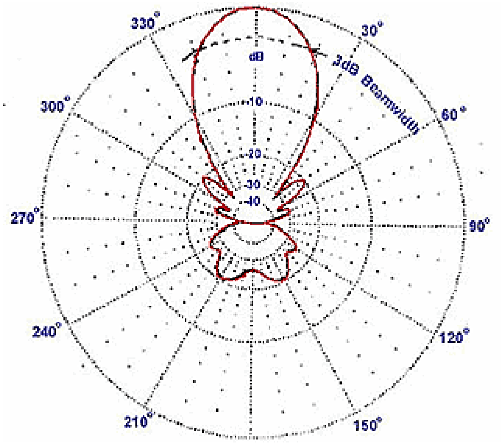

Figure.5: Polar radiation pattern for a tweeter at 4.5 kilo Hertz.

3. Experimental Results

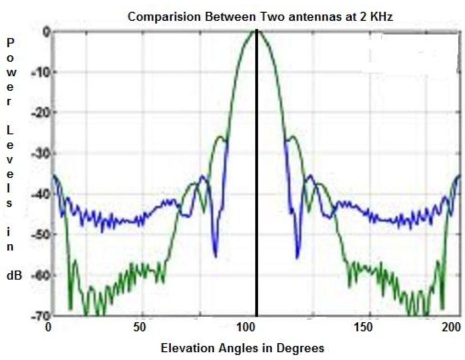

Figure.6: Normalized Radiation pattern of the uniform 8 x 8 tweeter array antenna at three frequency steps 2 kHz, and 4. KHz.

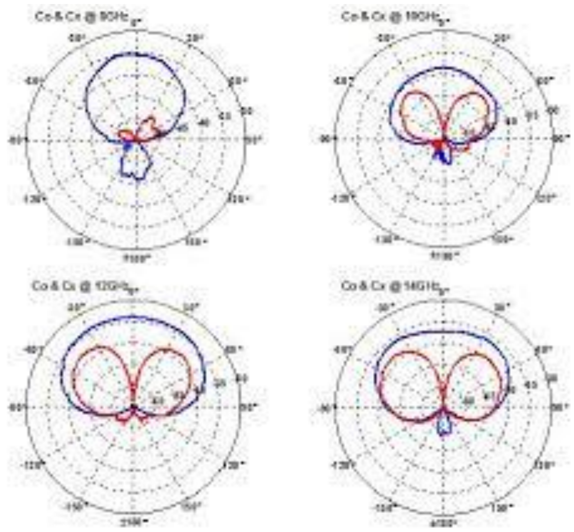

Figure.7: Normalized polar Radiation pattern of the uniform 8 x 8 different array antenna at three frequency steps 3.2 kHz, 3.3 kHz, 3.4 kHz.

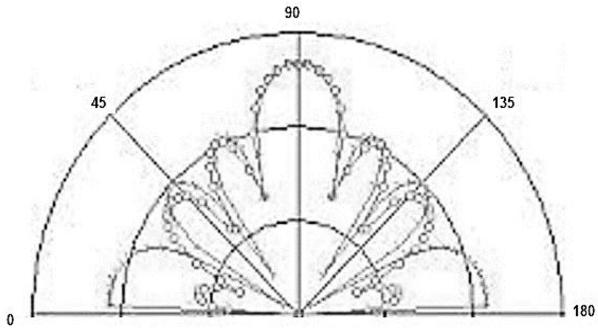

Figure.8: Normalized polar Radiation pattern of the uniform 8 x 8 Ahuja array antenna at three frequency steps 4.5 kHz, 4.6 kHz and 4.7 kHz.

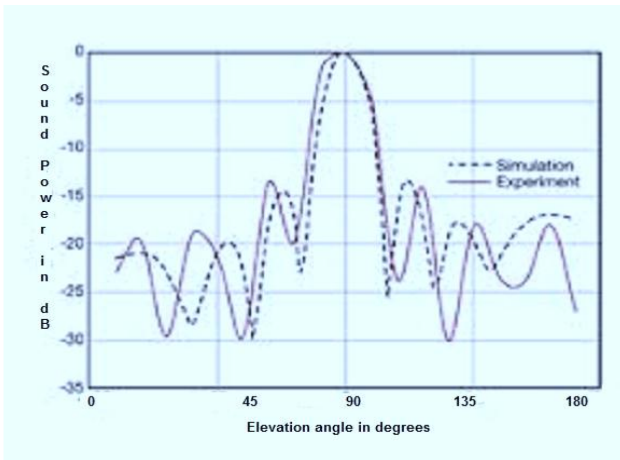

Figure.9: comparison between two different radiators w.r.t axial efficiency of array antenna.

4. Conclusions

Defining the parameters for SODAR system to using object- oriented application like MATLAB, will gives tremendous advantages. This object – oriented program are rich in structure, methods and attributes. Therefore utilizing of this software will reduce the cost effect, hardware compellability and can also use worldwide with Microsoft platform and other operating system platforms. Here in this paper, From the experimental measurements shows that tweeters impedance at f = 2 kilo Hertz is about 125 ohms and is equivalent to a 0.06 microfarad capacitance in parallel with at 1 k ohm resistor, which shows that the electrical power dissipated from 35 V_{rms} input is 0.06 watt. Therefore the electric- acoustic power conversion efficiency is around 50% at 1 kilo hertz and in and around 100% at 2 kilo Hertz and also concluded that for a 2 kilo Hertz system the horn would be about 170 mm along 54 mm diameter is well suited to get better mail lobe and as well as side lobe.

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