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A Simulation Research on Linear Beam Forming Transmission

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Abstract—**This paper presents Matlab simulation which was used to create a virtual environment using the graphical user interface that contains parameters to reproduce conditions in real environment situations. The system identifies the signal strength of a signal from an antenna array, which can be directional by using beam forming. The concept allows better reception for intended users and almost no signal for the non intended users.**

Keywords—**Beam forming, Linear Phased Array, Uniform Linear Array**

I. Introduction

In wireless communications, we aim to transmit signals at the users and eliminate the signals for non-intended users or if there are no users at all. The earlier solution for this was to use passive components such as reflectors, but these are costly and can only be applied to large applications such as satellites and microwave systems. In most applications such as wireless fidelity (wi-fi) or digital broadcasting, a passive use of reflectors is no longer practical. Instead, a beam forming is used. In beam forming, electronic steering is used to direct the signal to a user. Wireless communications rely on transmitters and that send signals in all directions to ensure that all users in the vicinity accepts a signal. This can be effective when sending few amounts of data and with only a few users. When transmitting high amounts of data, a directional approach of propagating the signal is used to ensure fast transmission and with few losses. One such technique is by using beam forming for which it directs a signal by using multiple antennas with phase shifting. A most common problem encountered in wireless communication is that users need to be in close proximity with transmitter to effectively communicate. This is because a single antenna can only transmit a small amount of data. The solution for this problem is to add more antennas, making an antenna array. The other problem concerns security. When data is transmitted wirelessly, the tendency is that the non-intended users also accept the signal. This compromises the privacy of the data of the users. The solution is to transmit the same signal from different antennas that add coherently at the user, and destructively at non-intended users [1]. The wireless communications are very common in today's society, since most users have gadgets with wireless devices and it demands very high amounts of data. The demand of such devices requires better transmitter provides good performance as well as security. These factors require new fields of research and study. This papers aims to: (a) show that beam forming is more efficient and effective than non directional transmission, (b) simulate environment that includes real life variables such as losses and interferences (c) identify the ideal and good number of antennas and operational frequency for beam forming. This paper is organized as it follows: Section II briefly presents the linear beam forming and also the methodology used in this research paper. Section III is devoted to the simulation results, which are carried out in order to verify the effectiveness of the proposed method by means of the Matlab environment. Conclusion ends the paper at section IV.

II. Methodology

This part explains the basics of beam forming and how it is used in wireless communications. The goal is simple, to increase the signal of the receiver, and reduce noise and interference coming from other sources. We want the signal to be aimed at a specific location where the receiver is located, rather than sending the signal to different directions.

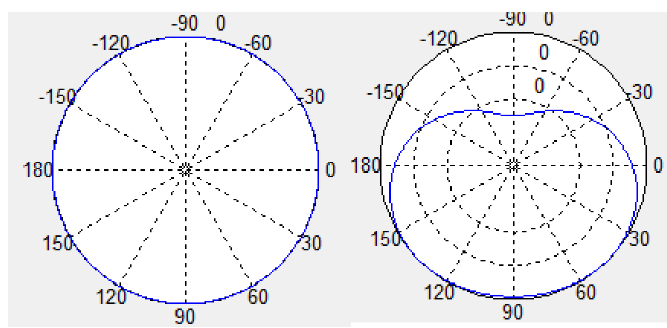

Fig. 1. Response of omni directional and focused beam pattern.

As shown in the figure, the response on the left is Omni directional, or being sent to all directions. This means that the signal is scattered and can be received by anyone. The response on the right, which is the focused beam pattern, is aimed only at the receiver for that specific data. By doing this, we improve the signal to noise ratio of the signal. One of the definitions of beam forming is that it does not need reflectors for directional transmission. As shown in Figure 2, the antenna elements have phase shifters, which allow for directional propagation. This method is known as electrical steering, since it uses circuits instead of reflectors. In this simulation, a phased linear array will be used to simulate a signal. A phased linear array has a simple construction. This is used when the signal is needed on a fixed area.

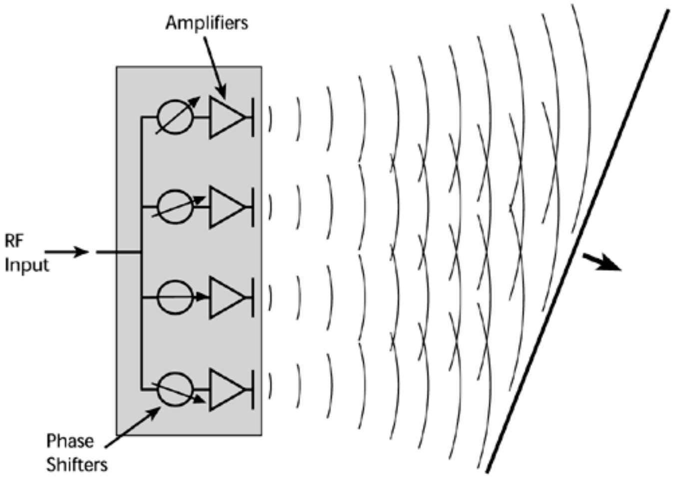

Fig. 2. Common setup for beam formers

The general form for the location of each element is given by:

$$d = [xyz] \tag{1}$$

$$y = \sum_{n=1}^{N} w_n x_n \tag{2}$$

$$\sin\theta = \frac{2}{N} - \frac{2\phi}{\pi} \tag{3}$$

$$\frac{SNR_{out}}{SNR_{in}} = \frac{\left(\dfrac{w^H v s^H w}{w^H N w}\right)}{\dfrac{s}{N}} = \frac{w^H v v^H w}{w^H w} \tag{4}$$

While the output of signal an antenna array is given by the equation (2) for which this equation is simply the summation of all the signals from each antenna element. Since a sine wave ranges from -1 to 1, we can see that the maximum energy can be attained by setting Φ to 1. From here, we can see that the maximum energy is at 90°. The use of arrays results in a significant amount of gain called array gain, which is the improvement between the array output and individual channel input. It is expressed by equation (4) where *w* is the vector of weights applied on the sensor array, *v* is the steering vector representing the array response toward a given direction, *s* is the input signal power, *N* is the noise power, and *H* denotes the complex conjugate transpose.

III. Simulation Results

The results were obtained using a Matlab simulation which is programmed in a graphical user interface (GUI) for easy and convenient data gathering. The default values use a test signal which is a common sine wave for easy analysis. The linear array antenna consists of 10 elements that operate at a frequency of 300 MHz.

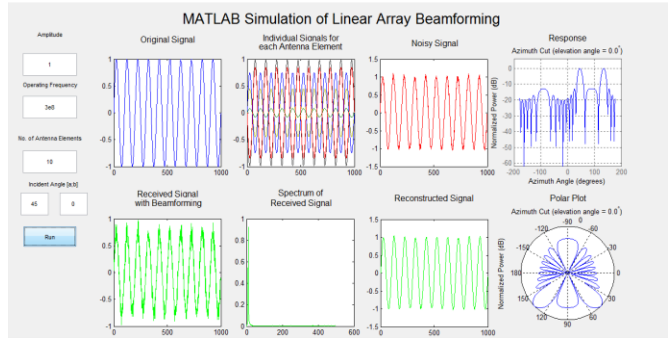

Fig. 3. GUI using a sine wave.

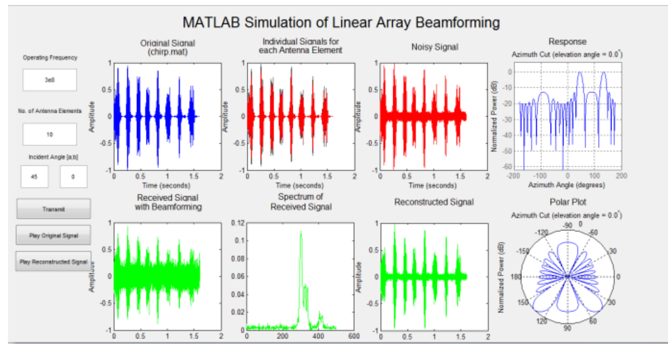

Fig. 4. GUI using an audio signal.

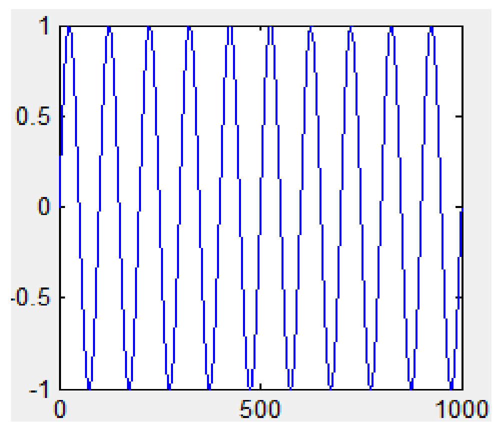

Fig. 5. Test signal.

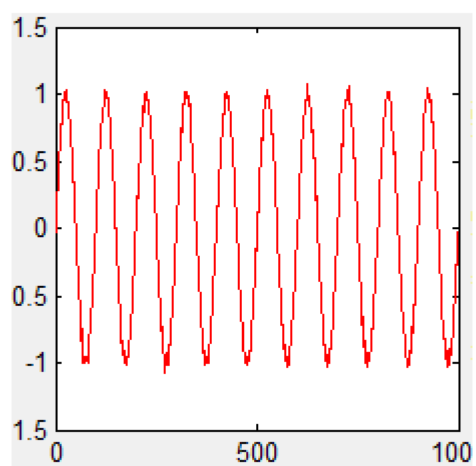

Fig. 6. Test signal with noise.

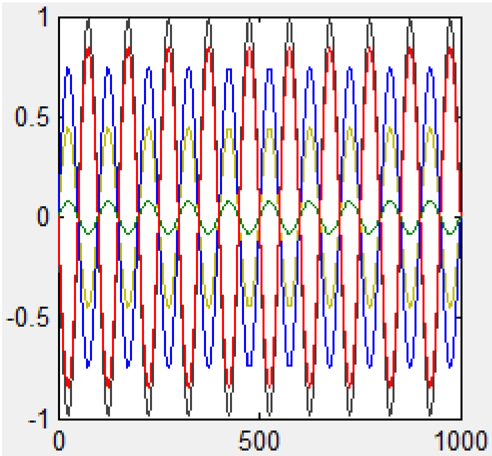

Fig. 7. Signals for each antenna element.

To make the simulation as realistic as much as possible, randomly generated noise was added to the signal, as shown in figure 6. In the figure shown above, the signal is sent to each of the ten antenna elements. It is noticeable that the signal has different amplitudes and different phases. These signals were generated using the phased.ULA syntax in Matlab which generates a uniform linear array of antennas at an operating frequency for which is user specified. The ten signals are then added to create a single signal. The output of the total signal is shown in figure 7. From this graph, it can be noticed that the signal has become thicker. This is due to the addition of signals each with an amount of random noise. Using a spectrum analyzer, the signal actually has a very minimal unwanted frequency, despite of its appearance. By observing the figure below, the magnitude of the test signal frequency is very high compared to the noise frequencies. As stated earlier, the use of beam forming results in a high signal to noise ratio.

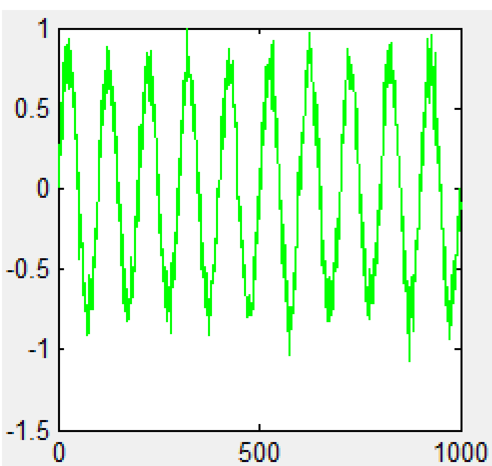

Fig. 8. Received beam formed signal.

Using a band pass filter, the original signal is recovered from the received signal. The result is a signal almost identical to the original signal, having very minimal or almost no distortions at all. On response plot of antenna array with default values while using the same data, the response of the antenna array was obtained.

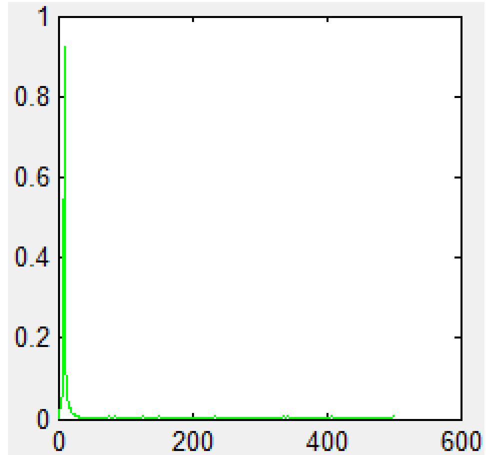

Fig. 9. Spectrum of received signal.

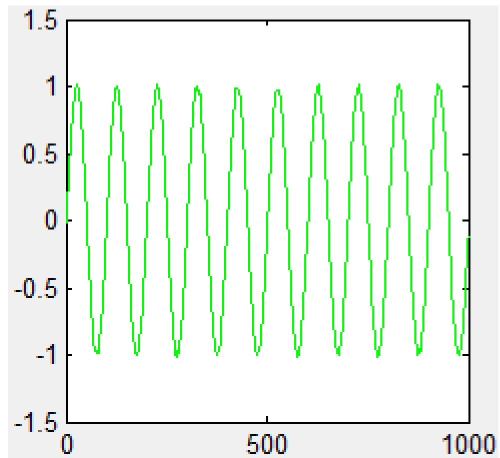

Fig. 10. Reconstructed signal.

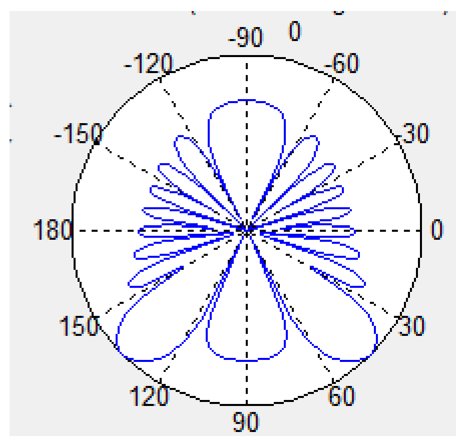

Fig. 11. Response plot for default values.

The plot as it is shown above shows the directions of signal propagation for ten antenna elements operating at 300 MHz. The graph shows three big lobes pointing downward, meaning that this is the area that has the strongest reception of the signal. For the response plot of antenna array with different values, the different values for the antenna elements and operating frequencies were used to observe the differences of their response plots.

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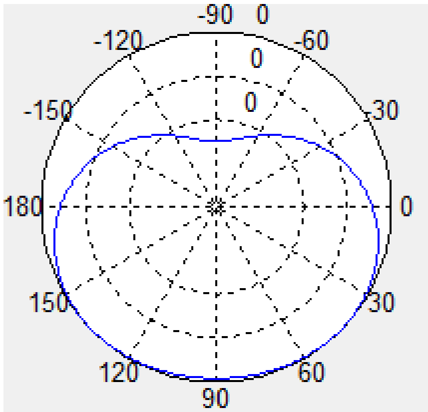

Fig.12. Response plot of 5 antenna elements operating at 3kHz.

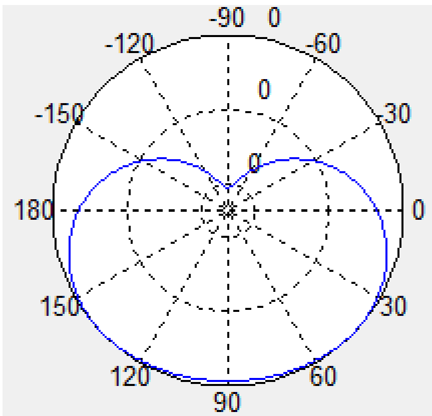

Fig.13. Response plot of 10 antenna elements operating at 3kHz.

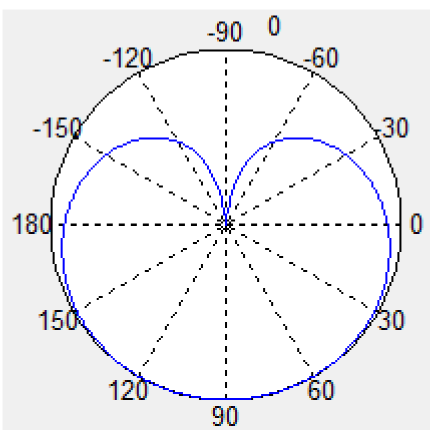

Fig.14. Response plot of 10 antenna elements operating at 3 kHz with incident angle of 90°

The response plot of antenna array with different values are compared to one another to determine if the frequency is feasible for beam forming and if the antenna elements are enough to achieve beam forming. From this figure, we can see that the signal is omni directional, meaning the signal is propagated at all directions, despite being configured for beam forming. This shows that these parameters are not practical for using beam forming. The response plot shown above shows that the signal is propagated in one area only. To improve the transmission, additional antenna elements can be added. The direction of propagation is improved by adding more antenna elements to the array. The figure is now in the shape of a cardioid. The transmission can also be improved by changing the incident angle. The new figure (figure 14) here shows that the signal is more focused, therefore giving more power. It was stated earlier in the mathematical equations that a 90° angle provides the maximum power for a phased array. For the results using an actual audio signal, the figure shown uses the sample audio from Matlab, the chirp.mat file.

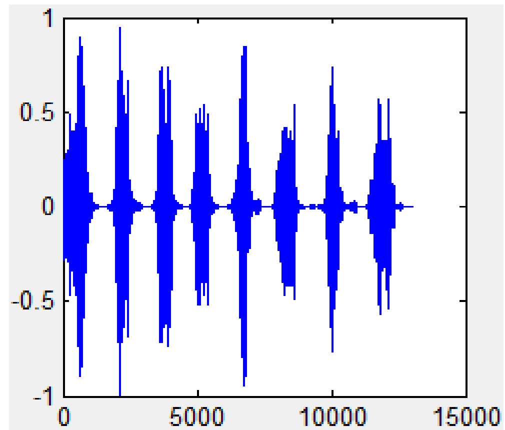

Fig.15. Input audio signal.

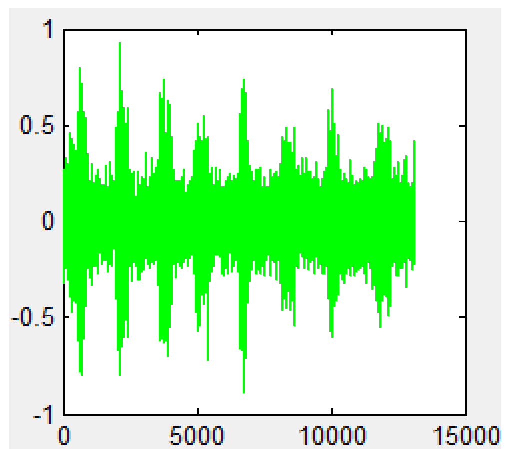

Fig.16. Beam formed audio signal.

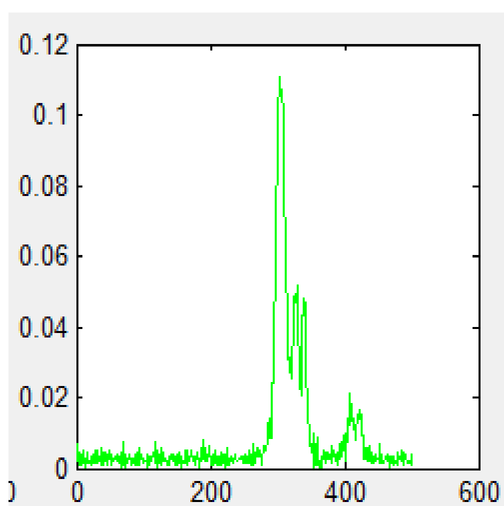

Fig. 17. Spectrum of beam formed audio signal.

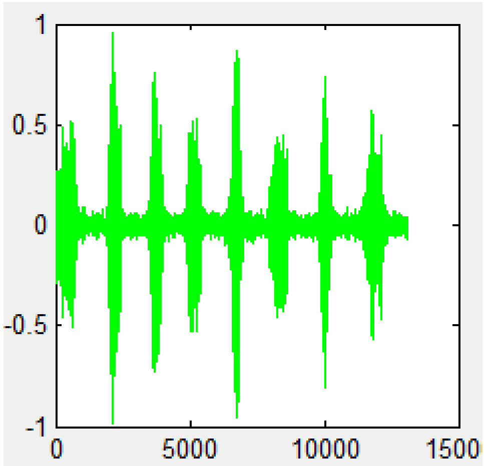

Fig. 18. Reconstructed signal.

The previous figures show the audio signal as a result of beam forming and the spectrum of the signal. We can observe that the frequency has a very high magnitude compared to the noise frequencies. The original signal can be extracted from the beam formed signal, with the use of a filter. The filtered signal is shown on the figure 18.

IV. Conclusion

This paper has presented a simulation research on linear beam forming transmission. The proposed system utilizes the principle of sending RF signals through a phased linear array. The signal is copied among the antenna elements, each with its own phase shifter and amplifier. The phase shifter, as described earlier, determines the direction of signal propagation. The signals are then amplified and sent to the area where the transmission is intended. Extensive simulation studies have been performed and carried out for the linear beam forming transmission to validate the study. Results have clearly confirmed that the linear beam forming transmission is remarkably effective. We can then recommend the use of the phased linear array beam former for transmission of data with high frequencies in areas where the transmission are only needed. Phased linear array antennas can have two or more antennas for which they are all equally spaced. The performance of the antenna increases with more antenna elements. The researchers would then therefore recommend further study and actual field testing.

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