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Design and Simulation of a Low-Cost Digital Beamforming (DBF) Receiver for Wireless Communication

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Abstract- Digital beam forming consists of the spatial filtering of a signal where the phase shifting, amplitude scaling and adding are implemented digitally. The idea is to use a computational and programmable environment which processes a signal in the digital domain to control the progressive phase shift between antenna elements in the array. Digital beamforming allows several attractive features in the performances of communication systems. The main advantage to be gained from digital beamforming is greatly added flexibility without any attendant degradation in signal-to-noise ratio (SNR).This research presents the design and simulation of a low cost Digital Beamforming (DBF) antenna. This DBF antenna can form part of the antenna structure in the receiver of the base station of a wireless communication system. The uniform amplitude weighting function is the beam pattern synthesis considered for the beam formation. The simulation is done in MATLAB.

Keywords: Beamforming, Antenna array, phased array

I. INTRODUCTION

Mobile communication system is one of the areas of communication that makes use of antenna extensively for its efficient operation. These antennas play vital roles since mobile communication system is made up of two distinctive parts; the physical parts and the wireless part. The antenna system is that structure that brings about the effective interactions of these two distinct parts. The antenna system simply put is that part of mobile communication system, which interfaces the physical part of the radio system and its wireless counterpart.

Traditionally, the antenna system is made up of single radiating element that sends or receives from all directions. But as improvement in antenna technology went on due to diversity in the applications of antenna, the antenna array which is the assembly of radiating elements gives the unique characteristics of beam-forming, which is utilize enormously in the design of beamforming antennas.

Beamforming antennas are the type of antenna array in which the radiation pattern is altered to have directivity in a particular direction [1]. This alteration of the pattern occurs as result of the phase and/or amplitude alteration of the signal entering each of the elements in the array.

The techniques for this alteration gives rise to the different types of beamforming antenna which include; the analog beam-forming antenna, in which the phase shift or phase delay is achieved by simply altering the length of cables to each element in the array, and the digital beam-forming in which the phase shifting, amplitude scaling and adding are implemented digitally.

The digital beamforming antenna in its simplest description is the marriage between the antenna technology and the digital technology [2]. It comprises of three major parts which are the antenna array, digital transceivers and the digital signal processor. Its operation is based on capturing Radio Frequency (RF) signals at each antenna elements and converting them into streams of binary base band (I and Q). Also included in the base band are the phase and amplitude of the signals received at each of the elements of the array. Beam forming is done by weighting these digital signals by adjusting their amplitudes and phases such that when added together they form the desired beam. This process is achieved by a special purpose Digital Signal Processor (DSP) chip. Digital beam formers can accomplish minimization of side lobes levels, interference cancelling, and multiple beam operation without changing the physical architecture of the phased array antenna. Every mode of the digital beam former is created and controlled by means of code written on a programmable device of the digital beam former [3].

II. RELATED WORKS

Nagpal and Filiba in [4] presented architecture for highly scalable and reusable time domain beam-former using a general purpose FPGA (Field Programmable Gate Arrays) boards. They also presented a comparable architecture for the same using DSP (Digital Signal Processor) chips. The FPGA design approach is based on the BEE2 plat form, system generality and reusability is the focus of their analysis, which assumes very little about the target antenna array and avoids any sort of tight coupling between subsystems. In their work, based on the FPGA approach, multiple FPGA boards are connected together to further scale the system arbitrarily in band width, polarization channels, and numbers of simultaneous beams. The connection topology can be modified for any configuration on the fly with soft ware control. From their analysis, they concluded that the DSP approach provides an attractive alternative to FPGA due to ease of programming and simulations.

Liang G., Gong W.B., Liu H.J. and Yu J.P. in [5] presented a 16 simultaneously steerable beam with detailed interface architecture and subunits. In this work, standard hexagonal array (SHA) and 61-channel RF front ends are designed. Genetic Algorithm is adopted to realize the pattern synthesis with multi-objective optimization. The signal flow and hardware platform of the digital beam-forming network are discussed,

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which can complete the high speed array signal processing with maximum throughput of 34.16 Gbps. They inferred that their work gave useful approach to control the radiation pattern by dint of digital processing at IF, as verified by the measurements. Ultimately, the measurements of array antenna show good agreement with the simulation result, which validates the rationality and feasibility of algorithms and project design. The successful implementation of DBF array enhances the possibility of DBF array antenna utilized for a new generation of Chinese LEO satellite

Michael Vandara in [6] reported that digital beam formers are a means for separating a desired signal from interfering signals. His work describes opportunities and constraints for application digital beam-forming techniques and adaptive beam-forming techniques in wireless communications. He concluded that Digital beam-forming allows several attractive features. Performances of communication systems can be improved while the digital beam-forming is used. The main advantage to be gained from digital beam-forming is greatly added flexibility without any attendant degradation in signal-to-noise ratio (SNR).

The goal of this work is to design a digital beam forming antenna with minimal cost as possible, and a simpler algorithm for mobile communication system.

III. FUNDAMENTALS OF BEAMFORMING

Beamforming simply means to focus energy along a specific direction, thus receiving or transmitting a signal in this direction, while rejecting signals from other directions. This is a unique property of the antenna array. It is simply the combination of radio signals from a set of small non directional antennas to simulate a large directional antenna. Beamforming is an alternative name for spatial filtering where, with appropriate analog or digital signal processing, an array of antennas can be steered in a way to block the reception of radio signals coming from specified directions [7, 8, 9]. While a filter in the time domain combines energy over time, the beam former combines energy over its aperture (e.g. space), obtaining a certain antenna gain in a given direction while having attenuation in others. Conceptually, beam forming is a signal processing technique used in sensor arrays for directional signal transmission or reception.

The traditional analog way to perform beam-forming is very expensive and it is sensitive to component tolerances and drifts, while modern technology offers high speed. Analog-to-Digital converters (A/D Converters) and Digital-Down Converters (DDC), are the fundamental blocks for digital beam forming. In both analog and digital domains, the most common methods used to create directional beams are the time delay (time shift) and the phase shifts respectively.

The time delay approach allows the formation and steering of beam by adding adjustable time delay steps that are independent from the operating frequency and bandwidth. Since it is difficult to generate time delay in the analog and digital domains, they are used only when strictly requested as with large arrays and/or when the bandwidth of the system is wide. In the case of phase shifting, a phase is introduced instead of applying true time delays for each receiver. It is simpler to introduce such compensation but unfortunately, this works properly only with narrow band systems and/or small arrays.

In the receiver beamformer, the signal from each antenna element may be simplified by different weights (w_n). Different weighting pattern can be used to achieve the desired sensitivity patterns. A main lobe is produced together with nulls and side lobes. As well as controlling the lobe width (the beam), and the side lobe levels, the position of a null can be controlled. This is useful to ignore noise or jammer in one particular direction, while listening for event in other directions. A similar result can be obtained during transmission.

Beam forming techniques can be broadly divided into two categories which are;

I. The analog beam forming
II. The digital Beam forming.

The digital beam forming is sub divided into two classes which are; the conventional (fixed) beam forming and the adaptive beam forming.

Analog Beam forming

Analog beam forming refers to the techniques where the application of the complex weights (w_n) is performed using analog beam forming networks that consist of analog components. The weights are usually fixed i.e. they do not change over time. In the millimeter (mm) bands, dielectric lenses are useful beam forming networks, however, in the mobile communication bands, beam forming networks consisting of general passive microwave components like phase shifters, hybrids, attenuators and combiners are preferred [10]. These may be realized in any suitable wave guide technology or as integrated components. A well known analog beam forming network capable of multi-beam operation is the ‘Butler Matrix’. This is the analog equivalent to spatial Fast Fourier Transform, because 2^n inputs signals produce 2^n orthogonal output signals (beams). The Fast Fourier Transform (FFT) twiddle factors are represented by phase shifters and summing is performed by hybrids.

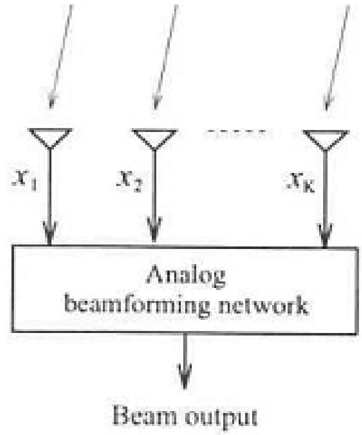

Figure 1 Analog beamforming network

Butler matrices are capable of high- power operation, and are comparatively cheap; hence this device is most often used in today’s so-called “Smart Antennas”. Switching between beams allows some limited form of adaptively to environmental changes. However, its ease of implementation in existing systems, much can be gained by this simple device.

Another use of Butler matrix is as a preprocessor for adaptive digital beam forming algorithms, thus enabling space operations.

Conventional Digital Beam Forming

Digital beam forming is simply the marriage between antenna technology and digital technology. The conventional beam former uses fixed sets of weightings and phase shifters or time delays to combine the signals from the sensors in the array, primarily using only the information about the location of the sensors in space and the wave dimensions of interest. Digital beam forming consists of the spatial filtering of a signal where the phase shifting, amplitude scaling and adding are implemented digitally. The idea is to use a computational and programmable environment which processes a signal in the digital domain to control the progressive phase shift between antenna elements in the array.

After the analog signals are converted to the digital domain by the analog-to-digital converters (ADC) and the digital down converters (DDC), beam forming is performed at the base band by weighting the received signal by multiplying with fixed predetermined weights. If the signal at the individual antennas are directly weighted and then combined, element-space beam forming is performed, which is the most common method. But if there was a preprocessing before weighting is performed such that a number of orthogonal beams are produced, and these are weighted before combining, beam-space beam forming is performed. The preprocessor itself may be implemented at the base band in the digital domain; this is advantageous if some prior information is available or if for some algorithms the dimension of the problem to solve is reduced.

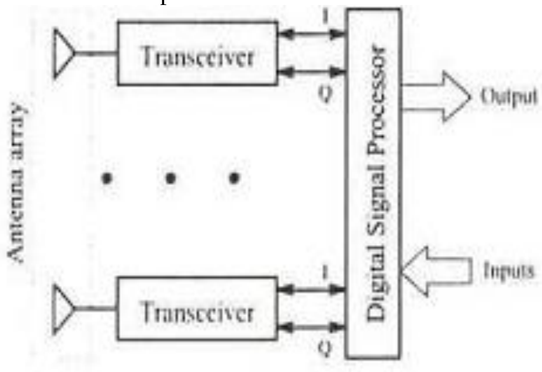

Figure 2 Digital beamforming network

Adaptive Beam-forming

The complex weights (w_n) for the antenna elements are carefully chosen to give the desired peaks and nulls in the radiation pattern of the antenna array. In a simple case, the weights may be chosen to give one central beam in some direction, as in a direction finding application. The weights could then be slowly changed to steer the beam until maximum signal strength occurs and the direction of the signal source is found.

In beam forming for communications, the weights are chosen to give a radiation pattern that maximizes the quality of the received signal. Usually, a peak in the pattern is pointed to the signal source and nulls are created in the direction of interfering sources and signal reflections.

Adaptive beam-forming is simply the process of altering the complex weights on-the-fly to maximize the quality of the communication channel. Some commonly used methods are

a. Minimum Mean-square-Error: The shape of the desired received signal wave form is known by the receiver. Complex weights are adjusted to minimize the mean-square error between the beam former output and the expected signal waveform.
b. Maximum Signal-to-Interference Ratio: Where the receiver can estimate the strength of the desired signal and of an interfering signal, weights are adjusted to maximize the ratio.
c. Minimum Variance: When the signal shape and source direction are both known, weights are chosen to minimize the noise on the beam former output.

Often, constraints are placed on the adaptive beam-former so that the complex weights do not vary randomly in poor signal conditions. Some radio signals include training sequences so that adaptive beam formers may quickly optimize its random pattern before the useful information is transmitted.

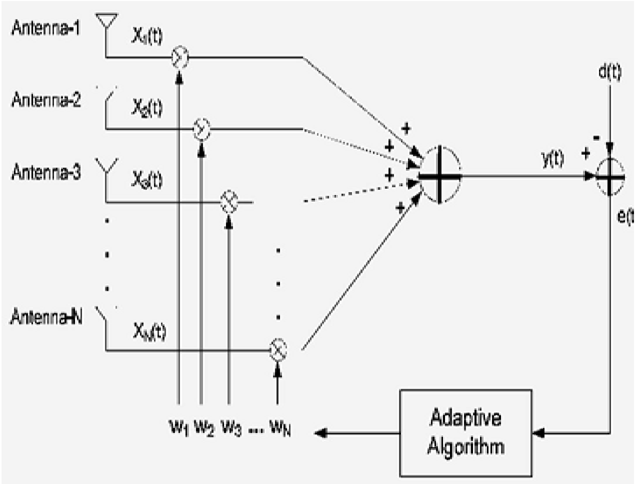

Fig 3 Adaptive Beamforming Network

IV. MATHEMATICAL MODEL OF DBF RECEIVER

The incident plane wave on an antenna array's receiver can be modeled by the following equation:

$$f(t,p_n) = c_n(t) = x(t-\tau_n)cos\big(w_{RF}(t-\tau_n)\big),\ \ n = 0, \ldots N-1$$
$$\approx x(t)cos(w_{RF}t-\theta_n), \qquad (1)$$

Where, $\theta_n$is given by

$$\theta_n = w_{RF}\tau_n \qquad (2)$$

After the incident plane wave has been received by the antennas of the phased array antenna (PAA), the in-coming signal arrives at the RF Modulation Stage. This stage is often required because the incoming signal's frequency components are high compared to the speed of the ADCs and analog signal modulation is needed to shift the signal's frequency components into a lower frequency band. If the RF Modulation Stage has a Local Oscillator (LO) with a frequency of,ω_{LO}, then the signal modulation operation can be described in the following form:

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$$g_n^{'} = x(t)cos(w_{RF}t - \theta_n)cos(w_{LO}t) \quad (3)$$

Using trigonometric identities, the signal $g_n(t)$ can be represented as a sum of two cosines:

$$g_n^{'}(t) = \frac{x(t)}{2}[cos(w_{IF}t - \theta_n)], \quad (4)$$

Where,

$$w_{IF} \triangleq w_{RF} - w_{LO}, \quad w_{IM} \triangleq w_{RF} + w_{LO}, \quad (5)$$

If a pass band filters with gain *G=2* are used centered at the signal's component with ω_{IF} as its center frequency, the output signal obtained is:

$$g_n(t) = x(t)cos(w_{IF}t - \theta_n). \quad (6)$$

The angular displacement, which represents the time delay of the incoming plane wave between the antennas of the array, is left unchanged in a modulation operation. After the incoming signal in an antenna channel has been modulated into an intermediate frequency and the signal higher frequency is at least half as small as the sampling frequency, the ADCs with a sampling rate T_S can be used to transform the signal into a digital representation:

$$g_n[m] = g_n(t) = x[mT_S]cos[w_{IF}mT_s - \theta_n] \quad (7)$$

To simplify the mathematical representation of the signal,$g_n[m]$, the constant T_S in the signal $x[mT_s]$ will be omitted and the variable $\omega_{IF} = w_{IF}T_s$ will be used to distinguish the cosine component in the digital signal representation from its analog representation. After making such simplifications, the digital signal observed in each DBF receiver channel *n* of the PAA is:

$$g_n[m] = x[m]cos[\omega_{IF}m - \theta_n] \quad (8)$$

It is important to observe that the digital representation of the DBF receiver signal contains the phase delay θ_n associated with the time delay found in each *n* element of the PAA.

After the antenna signal has been successfully sampled into the digital domain, the signal needs to be processed by the first stage of the DBF receiver, which is the Digital Down-Converter (DDC). The Digital Down-Conversion is performed by multiplying the digital signal with a sinusoidal signal and a 90° phase-shifted version of the sinusoidal signal, both generated by digital local oscillator. Both mathematical operations can be represented in the following form;

$$i_n^{'}[m] = g_n[m]cos[\omega_{DLO}m]$$
$$= x[m]cos[\omega_{IF}m - \theta_n]cos[\omega_{DLO}m] \quad (9)$$

and

$$q_n^{'}[m] = g_n[m]sin[\omega_{DLO}m]$$
$$= x[m]cos[\omega_{IF}m - \theta_n]sin[\omega_{DLO}m] \quad (10)$$

If the digital local oscillator frequency $\omega_{DLO} = \omega_{IF}$ the digital signals $i_n^{'}[m]$ and $q_n^{'}[m]$ for each DBF receiver channel can be represented in the following form:

$$i_n^{'}[m] = \frac{x[m]}{2}(cos[2\omega_{IF}m] + cos[\theta_n]), \quad (11)$$

$$q_n^{'}[m] = \frac{x[m]}{2}(sin[2\omega_{IF}m] + sin[\theta_n]). \quad (12)$$

The final step in the DDC stage of the DBF receiver is the filtering of the frequency component centered at the digital frequency $2\omega_{IF}$ for both digital signals (image frequencies). If a low-pass filters with a gain *G*=2 is used to process the signals $i_n^{'}[m]$ and $q_n^{'}[m]$, the output signals found in each filter are

$$i_n[m] = x[m]cos[\theta_n] \quad (13)$$

$$q_n[m] = x[m]sin[\theta_n] \quad (14)$$

It can be seen that the DDC stage of the DBF receiver transforms a digital band-pass signal with the time-delay θ_n into two digital baseband signals where the phase information of the band-pass signal is represented in the amplitude of both baseband signals. The previous transformation of the signal into its quadrature components is necessary in order to apply the next filtering phase as a double-input, double-output low-pass filter operation, which is equivalent to a single-input, single-output band-pass filter operation [10]. Figure 2.6 shows a block diagram of the RF modulator and the DDC stage of each antenna channel in the PAA with the mathematical equations derived previously.

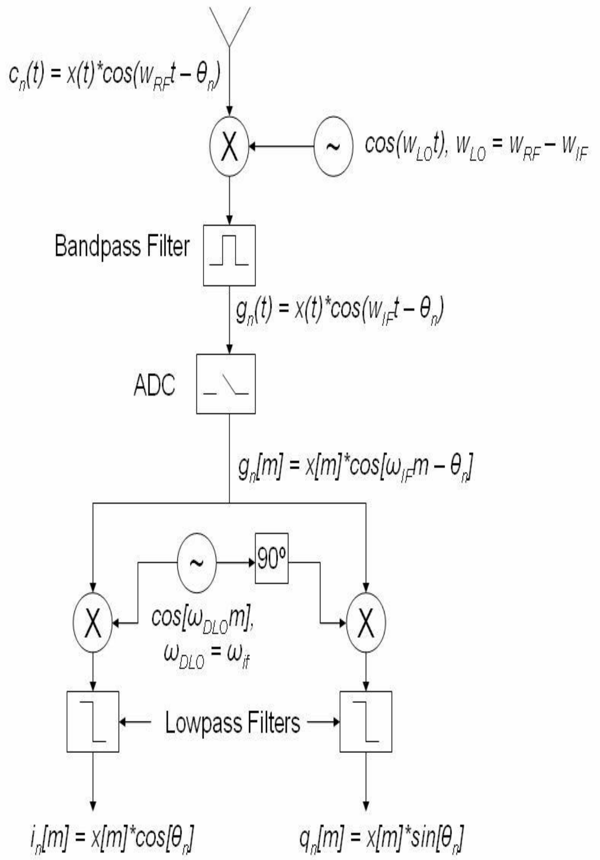

Figure 4: Block diagram (including equation) of RF modulators and DDC

The second stage of the DBF receiver is the Complex Weight Multiplication (CWM) stage. In this stage, the complex weight w_n^* associated with each antenna channel in the PAA is multiplied by the digital baseband signals $i_n[m]$ and $q_n[m]$. To represent this complex multiplication operation, a signal $b_n[m]$ will be defined which is composed of the signals $i_n[m]$ and$q_n[m]$:

$$b_n[m] = i_n[m] - jq_n[m]$$
$$= x[m](cos[\theta_n] - jsin[\theta_n])$$
$$= x[m]e^{-j\theta_n} \quad (15)$$

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It can be seen that the defined signal $b_n[m]$ is basically the signal *x[m]* multiplied by a complex constant with an associated phase, θ_n. To recover *x[m]*, the complex signal $b_n[m]$ has to be multiplied by the complex conjugate of the complex constant. In other words, if the complex weight, $w_n^* = e^{j\theta}$, then the product of the complex signal $b_n[m]$ and the complex weight is equal to the signal *x[m]*:

$$y_n[m] = w_n^* b_n[m] = e^{j\theta_n} x[m] e^{-j\theta_n} = x[m]. \quad (16)$$

It is important to emphasize that the application of the previous w_n^* assures phase coherency only with signals coming from space with a phase delay θ_n associated to its carrier signal. If the incoming signal is coming from another direction in space, the multiplication of the complex weight and the complex coefficient will not equal 1, thus making, $y_n[m] \neq x[m]$.

The CWM stage of the DBF receiver shown in Figure 5 is applied by means of multiplication and addition of real-value variables. To make such operations possible, it is necessary to express the complex weight w_n^* in rectangular form

$$w_n^* = Re\{w_n^*\} + jIm\{w_n^*\} \quad (17)$$

Once w_n^* has been represented in rectangular form, the resulting signal $y_n[m]$ can be obtained by applying the following mathematical operations:

$$\begin{aligned} y_n[m] &= w_n^* b_n[m] \\ &= (Re\{w_n^*\} + jIm\{w_n^*\})(i_n[m - jq_n[m]]) \\ &= r_n[m] + js_n[m] \quad (18) \end{aligned}$$

Where

$$r_n[m] = i_n[m]Re\{w_n^*\} + (-q_n[m])(-Im\{w_n^*\}) \quad (19)$$

$$s_n[m] = i_n[m]Im\{w_n^*\} + (-q_n[m])(Re\{w_n^*\}) \quad (20)$$

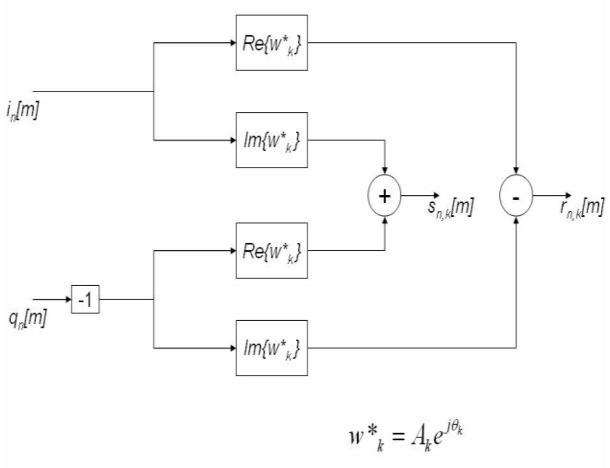

Figure 5: Block diagram of CWM phase

The last stage of the DBF receiver involves the addition of all the resulting signals, $y_n[m]$:

$$y[m] = \frac{1}{N}\sum_{n=0}^{N-1} y_n[m] = \frac{1}{N}\sum_{n=0}^{N-1} r_n[m] + j\frac{1}{N}\sum_{n=0}^{N-1} s_n[m]$$

$$= r[m] + js[m] \quad (21)$$

An amplitude scaling by a factor of *N* is needed to recover *x[m]* without gain. If desired, the amplitude scaling factor can be included in the complex weight coefficient and omitted in the last phase of the DBF receiver. The signals *r[m]* and *s[m]*, which are the output of the DBF receiver, are the quadrature components of the resulting signal *y[m]*. Post-processing of this quadrature signals, which is done by other components of the system where the PAA is used, is needed for proper retrieval and analysis of the information signal *x[m]*.

V. DBF RECEIVER DESIGN

The physical design of a DBF Receiver is based on the mathematical model described in the previous section. The design of the DBF Receiver considers how the mathematical model can be implemented using real components and takes into account limitations found in the physical implementation of the PAA system. The design of the DBF Receiver can be divided into four main components: RF Modulation Stage, Digital-Down Conversion stage, Complex Weight Multiplication stage, and the Summation stage. It is important to remember that the RF Modulation Stage is not implemented digitally (technically, it is not part of the Digital Beam-former), but it is essential in the implementation of the PAA.

The first stage of the DBF Receiver (the second stage in antenna channel) is the Digital-down Conversion Stage. The DDC receives an incoming digital IF signal (Usually from an ADC), and modulates the signal into baseband and produces an in-phase signal and a quadrature signal as outputs. The design of the DDC can be implemented using FPGAs or dedicated ICs. The quadrature modulation is performed by the multiplication of the IF signal with a digital oscillator, as mentioned in the previous section. The implementation of the digital oscillator is accomplished using a direct digital synthesizer (DDS). Direct digital synthesis is a technique by which a sinusoidal signal is created by the generation of digital numbers which controls the input of a sinusoidal look-up table [12].

The second stage in the DBF receiver (third stage in antenna channel) is the CWM stage. The CWM receives the in-phase baseband signal, the quadrature baseband signal, and the magnitude of the complex weight and the phase of the complex weight as inputs. The CWM phase can be implemented using 7 multiplication operations and 2 addition operations per channel. The first 3 multiplication operations are the product of the complex weight's amplitude with the sine, the negative side, and the cosine of the complex weight's phase which gives the real, imaginary, and negative imaginary part of the complex weight respectively. The other 4 multiplication operations are the product of the real and imaginary parts of the complex weight with the in-phase and quadrature baseband signals. Finally, the 2 addition operations add the resulting in-phase baseband result and the resulting quadrature baseband result in each channel. Also, 2 negation operators are needed to calculate the negative value of the quadrature baseband signal and the negative sine function and a sine look-up table is necessary to evaluate the sine and cosine function of the complex weight's phase

The final stage in the DBF Receiver is the Summation Stage. In this stage, the in-phase baseband signals and the quadrature baseband signals of all the antenna channels are added to give a final in-phase baseband signal and quadrature baseband signal as outputs of the DBF receiver.

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The number of addition operations in this stage depends on the number of antenna channels in the PAA. The two resulting signals can be used in subsequent stages to process and analyze the data received in the information signal by the PAA.

VI. SIMULATION AND RESULTS

This section presents and describes MATLAB simulation of the designed DBF receiver antenna. The beam pattern simulated describes the beam pattern whose angle of Main Response Axis (MRA) is 50°, formed by spatial filtering using the uniform amplitude weight function.

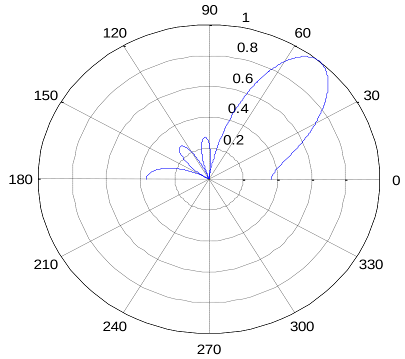

Figure 6: Polar Graph of Beam Pattern Magnitude of a 4-element linear DBF pointing at

$$\theta_{MRA} = 50$$

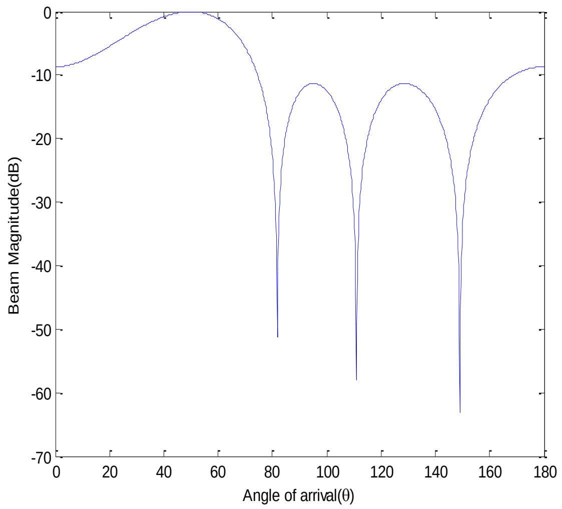

Figure 7: Rectangular Plot of Beam Pattern Magnitude of a 4-element linear DBF pointing to $\theta_{MRA} = 50°$

Figures 6 and 7 show that when the number in the array is 4, the simulation result obtained gave a directivity gain of 6.02dB, the weight amplitude of 0.25, and a beam width of 40.5° pointing at the angle of 50°.

On altering the number of elements in the array, changes begin to appear on the characteristics of the beam pattern. When the number of element is increased to 8, the directivity gain in dB increased to 9.03 dB, and the weight amplitude was reduced to 0.125, the beam width in degree also reduced to 20° pointing at an angle of 50°.

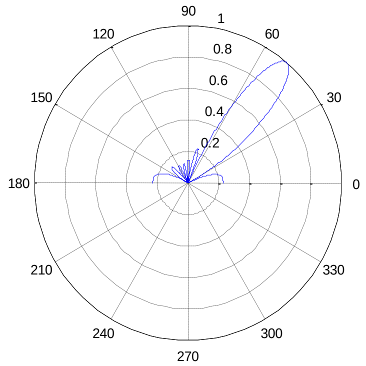

Figure 8: Polar Graph of Beam Pattern Magnitude of an 8-Element linear DBF pointing at $\theta_{MRA} = 50°$

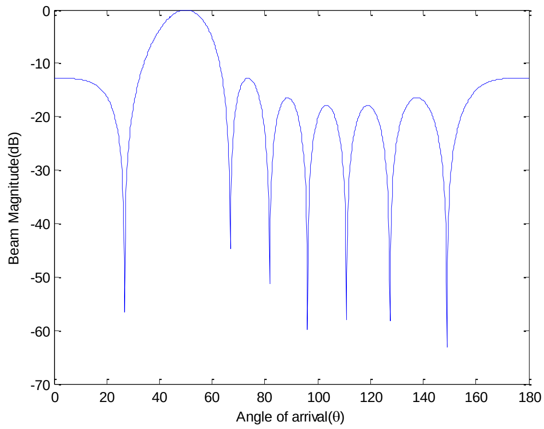

Figure 9: Rectangular Plot of Beam Pattern Magnitude of an 8-Element Linear DBF pointing at $\theta_{MRA} = 50°$

Next the calculation of the weight coefficients was performed using the Null placement method, which can position a maximum of N-1 nulls for an N-element PAA. The simulation is to compare the performance and characteristics of a DBF linear PAA with respect to the number of element in the array. The performance and characteristics here include; the various angles of arrival, the directivity, the null depths, the half power beam width etc. When the number of elements in the array is 4, the simulation results obtained showed the nulls placed at angles of arrivals of 30, 60 and 100, from the right-side end fire with null depths of -60dB, -56dB, and -47dB respectively. The directivity gain in dB is 5.73dB.

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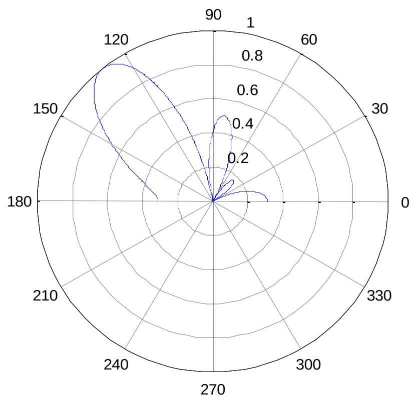

Figure 10: Polar Graph of a 4-Element Linear PAA with Beam Pattern Nulls Placed at 30°, 60° and 100°

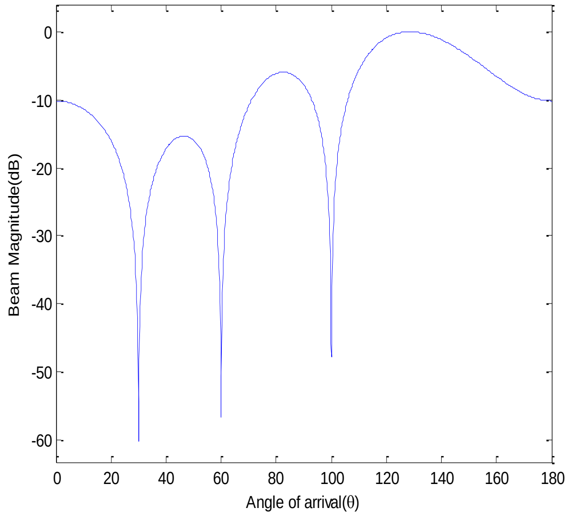

Figure 4.8: Rectangular Plot of Beam Pattern Magnitude of a 4-Element Linear DBF with Beam Pattern Nulls Placed at 30°, 60 and 100°

Table 1: Beam Pattern Characteristics Result for 4-Elements Linear PAA for Nulls Placed at 30°, 60° and 100°

Beam Pattern Characteristics	**Results**
Null #1: Angle of Arrival	$\theta_{\#1} = 30°$
Null depth of Null #1	$\lvert B(\theta_{\#1})\rvert_{dB} = -60dB$
Null #2: Angle of Arrival	$\theta_{\#2} = 60°$
Null depth of Null #2	$\lvert B(\theta_{\#2})\rvert_{dB} = -56dB$
Null #3: Angle of Arrival	$\theta_{\#3} = 100°$
Null depth of Null #3	$\lvert B(\theta_{\#3})\rvert_{dB} = -47dB$
MRA angle-of- arrival	$\theta_{MRA} = 130°$
Half power Beam-width	$\theta_{BW} = 35°$
Directivity	$D_{dB} = 5.73dB$
Side-lobe level	$SLL_{dB} = -6dB$

VII. CONCLUSION

After comparing the beam pattern results obtained with respect to the different numbers of elements in the array, it can be seen that the number of elements in the array to a reasonable extent, affect the performance and characteristics of a linear PAA, implemented by DBF techniques. The results obtained in the first spatial filtering i.e. synthesis of beam pattern using the uniform amplitude weights function, showed that alterations in the number of leads to corresponding changes in the directivity gains. When the number of elements was increased from four to eight, the directivity gain also increased 6.02dB to 9.03dB, and when the elements number was reduced to 2, the directivity gain was correspondingly reduced to 3.01dB. Also, the weight amplitudes on each element, which occurs as a result of the current entering each element is also affected by the changes that occur in the number of elements. When the number of elements was increased from four to eight, the weight amplitude decreased from 0.25 to 0.125, thereby requiring small currents entering the elements, and when the elements number was reduced to two, the weight amplitude increased to 0.5, thereby requiring large currents to enter the elements.

Following the results obtained in the simulation, it can be seen that the linear PAA digital beam forming receiver can serve in several applications in wireless communication system. This can be where a receiving antenna at a base station needs to receive an intelligent signal in the midst of interfering signals, by using the null placement method, the DBF receiving antenna can be made to set its nulls to the direction of these interfering signals in order to achieve good quality intelligent signal. Again, the DBF achieved by the null placement method can be used to achieve communication of classified information from sources located at different locations that needs to send information at the same time to one receiver.

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