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Analysis of Antenna through Non Uniform Dolph - Tchebyscheff Arrays Polar and Cartesian Plots

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Abstract – This project explores the analytical methods of synthesizing linear antenna arrays. The synthesis employed is based on non-uniform methods. In particular, the Dolph-Chebyshev is used, so as to improve the directivity of the array and to reduce the level of the secondary lobes by adjusting the geometrical and electric parameters of the array. The radiation patterns, the directivity, and the array factors of the uniform and the non-uniform methods are presented. It is shown that the Chebyshev arrays have better directivity than any other array type like binomial arrays for the same number of elements and separation distance. Finally, a numerical result is analyzed through radiation pattern through Polar and Cartesian plots.

Index Terms – Antenna arrays,non uniform arrays, dolph Tscebyscheff arrays.

1. INTRODUCTION

In radio and electronics,an antenna (plural antennae or antenn as), or aerial, is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC)) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified.

Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

2. CHARACTERISTICS OF ANTENNA

Antennas are characterized by a number of performance measures which a user would be concerned with in selecting or designing an antenna for a particular application. Chief among these relate to the directional characteristics (as depicted in the antenna's radiation pattern) and the resulting gain. Even in omnidirectional (or weakly directional) antennas, the gain can often be increased by concentrating more of its power in the horizontal directions, sacrificing power radiated toward the sky and ground. The antenna's power gain (or simply "gain") also takes into account the antenna's efficiency, and is often the primary figure of merit.

Resonant antennas

The majority of antenna designs are based on the resonance principle. This relies on the behavior of moving electrons, which reflect off surfaces where the dielectric constant changes, in a fashion similar to the way light reflects when optical properties change. In these designs, the reflective surface is created by the end of a conductor, normally a thin metal wire or rod, which in the simplest case has a feed point at one end where it is connected to a transmission line. The conductor, or element, is aligned with the electrical field of the desired signal, normally meaning it is perpendicular to the line from the antenna to the source (or receiver in the case of a broadcast antenna).

Current and voltage distribution

The quarter-wave elements imitate a series-resonant electrical element due to the standing wave present along the conductor. At the resonant frequency, the standing wave has a current peak and voltage node (minimum) at the feed. In electrical terms, this means the element has minimum reactance, generating the maximum current for minimum voltage. This is the ideal situation, because it produces the maximum output for the minimum input, producing the highest possible efficiency. Contrary to an ideal (lossless) series-resonant circuit, a finite resistance remains (corresponding to the relatively small voltage at the feed-point) due to the antenna's radiation resistance as well as any actual electrical losses.

Electrically short antennas

It is possible to use simple impedance matching concepts to allow the use of monopole or dipole antennas substantially shorter than the ¼ or ½ wavelength, respectively, at which they are resonant. As these antennas are made shorter (for a given frequency) their impedance becomes dominated by a series capacitive (negative) reactance; by adding a series inductance with the opposite (positive) reactance – a so-called loading coil – the antenna's reactance may be cancelled leaving only a pure resistance. Sometimes the resulting (lower) electrical resonant frequency of such a system (antenna plus matching network) is described using the concept of electrical length, so an antenna used at a lower frequency than its resonant frequency is called an electrically short antenna.

The amount of signal received from a distant transmission source is essentially geometric in nature due to the inverse-square law, and this leads to the concept of effective area. This measures the performance of an antenna by comparing the amount of power it generates to the amount of power in the original signal, measured in terms of the signal's power density in Watts per square metre. A half-wave dipole has an effective

area of 0.13 {\displaystyle \lambda } 2. If more performance is needed, one cannot simply make the antenna larger. Although this would intercept more energy from the signal, due to the considerations above, it would decrease the output significantly due to it moving away from the resonant length. In roles where higher performance is needed, designers often use multiple elements combined together.

Bandwidth

Although a resonant antenna has a purely resistive feed-point impedance at a particular frequency, many (if not most) applications require using an antenna over a range of frequencies. The frequency range or bandwidth over which an antenna functions well can be very wide (as in a log-periodic antenna) or narrow (in a resonant antenna); outside this range the antenna impedance becomes a poor match to the transmission line and transmitter (or receiver). Also in the case of the Yagi-Uda and other end-fire arrays, use of the antenna well away from its design frequency affects its radiation pattern, reducing its directive gain; the usable bandwidth is then limited regardless of impedance matching.

Gain

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will radiate most of its power in a particular direction, while a low-gain antenna will radiate over a wider angle. The antenna gain, or power gain of an antenna is defined as the ratio of the intensity (power per unit surface area) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna which radiates equal power in all directions. This dimensionless ratio is usually expressed logarithmically in decibels, these units are called "decibels-isotropic" (dBi)

$$G_{db}i=10\log(I/I_{iso})$$

A second unit used to measure gain is the ratio of the power radiated by the antenna to the power radiated by a half-wave dipole antenna ,these units are called "decibels-dipole" (dBd)

$$G_{dbd}=10\log(I/I_{dipole})$$

Since the gain of a half-wave dipole is 2.15 dBi and the logarithm of a product is additive, the gain in dBi is just 2.15 decibels greater than the gain in dBd

$$G_{dbi}=G_{dbd}+2.15$$

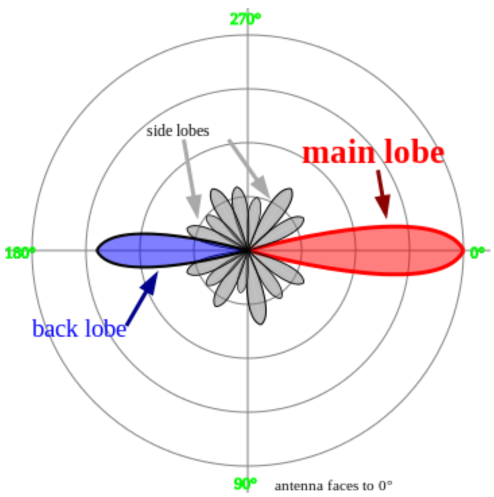
High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully at the other antenna. An example of a high-gain antenna is a parabolic dish such as a satellite television antenna. Low-gain antennas have shorter range, but the orientation of the antenna is relatively unimportant. An example of a low-gain antenna is the whip antenna found on portable radios and cordless phones. Antenna gain should not be confused with amplifier gain, a separate parameter measuring the increase in signal power due to an amplifying device.

Effective area or aperture

The effective area or effective aperture of a receiving antenna expresses the portion of the power of a passing electromagnetic wave which it delivers to its terminals, expressed in terms of an equivalent area. For instance, if a radio wave passing a given location has a flux of 1 pW / m2 (10−12 watts per square meter) and an antenna has an effective area of 12 m2, then the antenna would deliver 12 pW of RF power to the receiver (30 microvolts rms at 75 ohms). Since the receiving antenna is not equally sensitive to signals received from all directions, the effective area is a function of the direction to the source.

Radiation pattern

The radiation of many antennas shows a pattern of maxima or "lobes" at various angles, separated by "nulls", angles where the radiation falls to zero. This is because the radio waves emitted by different parts of the antenna typically interfere, causing maxima at angles where the radio waves arrive at distant points in phase, and zero radiation at other angles where the radio waves arrive out of phase. In a directional antenna designed to project radio waves in a particular direction, the lobe in that direction is designed larger than the others and is called the "main lobe". The other lobes usually represent unwanted radiation and are called "side lobes". The axis through the main lobe is called the "principal axis" or "boresight axis".



Impedance matching

Maximum power transfer requires matching the impedance of an antenna system (as seen looking into the transmission line) to the complex conjugate of the impedance of the receiver or transmitter. In the case of a transmitter, however, the desired matching impedance might not correspond to the dynamic output impedance of the transmitter as analyzed as a source impedance but rather the design value (typically 50 ohms) required for efficient and safe operation of the transmitting circuitry. The intended impedance is normally resistive but a transmitter (and some receivers) may have additional adjustments to cancel a certain amount of reactance in order to "tweak" the match. When a transmission line is used in between the antenna and the transmitter (or receiver) one generally would like an antenna system whose impedance is resistive and near the characteristic impedance of that transmission line in order to minimize the standing wave ratio (SWR) and the increase in transmission line losses it entails, in addition to supplying a good match at the transmitter or receiver itself.

3. LITERATURE REVIEW

According to Design of Non-Uniform Antenna Arrays Using Genetic Algorithm by Murad Ridwan1, Mohammed Abdo, Eduard Jorswieck "The performance of a single-element antenna is somewhat limited. To obtain high directivity, narrow beam-width, low side-lobes, point-to-point and preferred-coverage pattern characteristics, etc., antenna arrays are used. An antenna array is an assembly of individual radiating antennas in an electrical and geometrical configuration. Nowadays, antenna arrays appear in wireless terminals and smart antennas, so robust and efficient array design is increasingly becoming nec-essary. In antenna array design, it is frequently desirable to achieve both a narrow beamwidth and a low side-lobe level. In linear antenna arrays, a uniform array yields the smallest beamwidth and hence the highest directivity. It is followed, in order, by the Dolph-Chebyshev and Binomial arrays. In contrast, Binomial arrays usually possess the smallest side-lobes followed, in order, by the Dolph-Chebyshev and uniform arrays.Binomial and Dolph-Chebyshev arrays are typical examples of non-uniform arrays. In this paper we deal only with linear arrays and it is shown that using genetic algorithm it is possible to design a non-uniform array that approximates the beamwidth of a uniform array and having smaller side-lobe level than the Dolph-Chebyshev array. The result is that the designed antenna array exhibits the largest directivity as compared to the uniform, Binomial and Dolph-Chebyshev arrays. In the design, the genetic algorithm is employed to generate the excitation amplitudes of the antenna array."

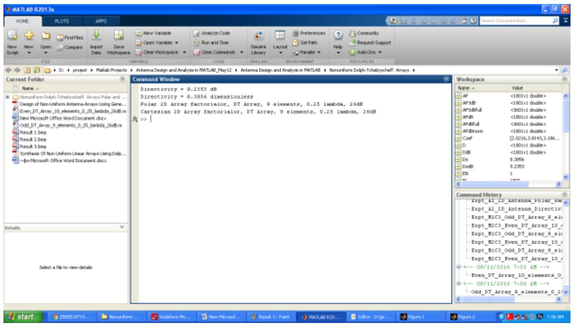
According to Synthesis Of Non Uniform Linear Arrays Using Dolph – Chebyshev Polynomial By Reducing Side Lobe Level Based On Modulating Parameter Array Factor by S.Ruksana Begum, G.Ramarao propose a new approach to reduce the first side lobe level of an antenna array, without disturbing the main beam width using doplh – chebyshev array. There are number of Techniques used to reduce Side Lobe Level (SLL) of antenna arrays to save power and improve Quality of Service (QoS) by ensuring maximum radiation in desired direction, several methods are available in literature. However, in the present work, an array for a specified first side lobe level of -35dB was synthesized using Dolph Chebyshev method. The weighting vectors are compared. Using these vectors, patterns are generated for arrays of different elements. The resultant patterns are compared and the result shows greater improvement in the SLL reduction from the Dolph Chebyshev method without deteriorating the main beam width.

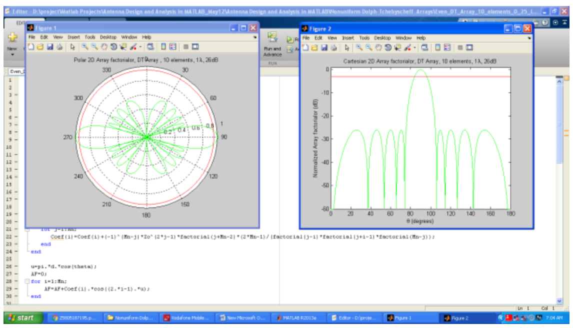
4. METHODLOGY

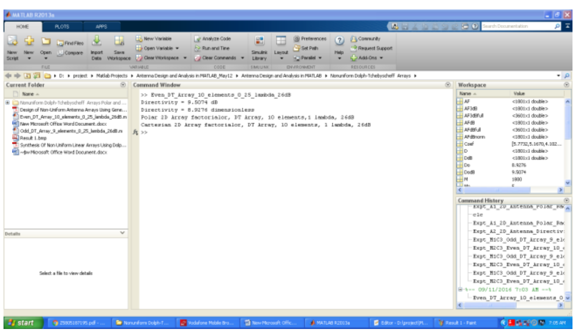
We propose a Dolph – chebyshev array method to synthesize the array beam pattern of a Non Uniform Linear Array (NULA) based on the properties of Chebyshev polynomials. For a given Side-Lobe Level (SLL), it has been proven that the Dolph-Chebyshev array provides narrowest main beam width in the array beam pattern, while for a given main beam width, it achieves the lowest SLL.

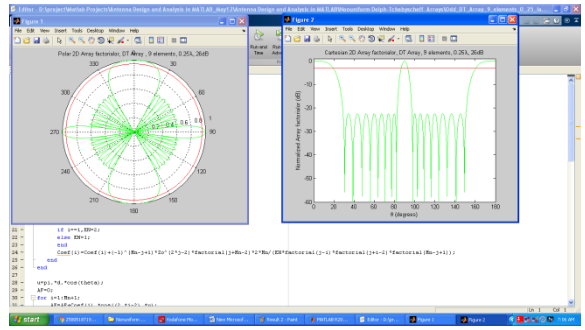
Dolph proposed (in 1946) a method to design arrays with any desired side-lobe levels and any HPBWs. This method is based on the approximation of the pattern of the array by a Chebyshev polynomial of order n, high enough to meet the requirement for the side-lobe levels.

5. RESULTS









6. CONCLUSION

It is shown that the Chebyshev arrays have better directivity than any other array type like binomial arrays for the same number of elements and separation distance. Finally, a numerical result is analyzed through radiation pattern through Polar and Cartesian Plots.

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