New Multiband Design Using Chebyshev Distribution
For Broadband & Military Applications

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ABSTRACT

A different kind of approach was employed in designing a multi-band antenna by using chebyshev distribution to fulfill broadband and military applications on FR4 substrate. The presented approach is based on combining a rectangular and a equilateral triangular patch with proper slots placed on each part and is simulated using concerto software. By changing certain feed position only we can achieve desired application within single antenna this type of antenna can be used in several applications especially in the CMOS/CMOD downlink military purposes Wi-Fi, Bluetooth and WI Max applications.

Keywords: Multi-band antenna, broadband and military applications, Chebyshev Distribution

1. INTRODUCTION

Numerous applications were developed after designing of multiband antennas with switchable slots and also to avoid using of two antennas. In [1]. Multi band patch with shorting wall and slot was proposed in order to achieve different wireless applications wideband was achieved by using a slot on top patch. A similar approach was presented in [4] where a single low profile printed antenna which provides dual-band operation by having two-step slots loading embedded close to the radiating edge. In [4], it was also shown that the ratio of the two frequencies can be well controlled by the aspect ratio of the step-loading dimension the multiband CPW-fed slot antenna with L-slot bowtie tuning stub was presented with simulation and measurement results. From measured results, the proposed antenna is appropriated to apply for communication systems of PCS 1900, UMTS, WLAN 802.11a/b/g. Furthermore, the proposed antenna has an omni -direction pattern for all frequency bands signifying that the proposed antenna is suitable for using in wireless communications in [5]. In [6], an antenna with frequency of 4.2GHz collinear antenna is designed to be used for Computer Management of Vehicles/Communication Mobile (CMOV/COMOB) application. The CMOV/ COMOB is a radar platform and a moving communication utility that can be integrated into combat systems, that is Air Defense System (ADS) and Combat-field Management System (CMS). One of the features is for satellite communication which is called small earth station (SBM: Stasiun Bumi Mini) that usually uses parabola-type reflector. Here, the collinear antenna is proposed to replace the parabola antenna system because of its cost and dimension.

This paper presents a multi-band antenna design approach based on inserting rectangular slots, following a Chebyshev distribution, in a rectangular patch and adding a triangular slot into an equilateral triangular patch as shown in Figure 1. The whole system is being fed by a wire edge into the substrate with input impedance of 50 Ohm. Several results are presented and discussed to show the versatility of this antenna. The proposed antenna has many applications and can be used to cover WI-FI, WIMAX, Video Wireless Communication, and Bluetooth applications. The concept of inserting slot arrays following a known chebyshev distribution has proven to give remarkable versatility to an antenna

2. CHEBYSHEV DISTRIBUTION

In probability theory, Chebyshev’s inequality (also spelled as Tchebysheff’s inequality) guarantees that in any data sample or probability distribution, “nearly all” values are close to the mean — the precise statement being that no more than 1/k^2 of the distribution’s values can be more than k standard deviations away from the mean. The inequality has great utility because it can be applied to completely arbitrary distributions (unknown except for mean and variance), for example it can be used to prove the weak law of large numbers.

\[ \Pr \left( |x-\mu| \geq k\sigma \right) \leq \frac{1}{k^2} \]

Chebyshev's inequality ensures that, for all distributions for which the standard deviation is defined, the amount of data within a number of standard deviations of the mean This theorem will typically provide rather loose bounds. However, the bounds provided by Chebyshev’s inequality cannot, in general (remaining sound for variables of arbitrary distribution), be improved upon. For example, for any k \geq 1, the following example meets the bounds exactly.
For this distribution, mean $\mu = 0$ and standard deviation $\sigma = 1/k$, so. For any normal distribution, about 68% of results will fall between +1 and -1 standard deviations from the mean, and about 95% will fall between +2 and -2 standard deviations. Chebyshev’s Theorem allows you to extend this idea to any distribution: even if that distribution isn’t normal. The theorem states that for a population or sample, the proportion of observations is no less than $1 - (1 / k^2)$, as long as the z score’s absolute value is less than or equal to $k$. You can only use Chebyshev’s Theorem to results for standard deviations over 1.

### 3. DESIGN OF ANTENNA

The basic structure of the proposed antenna, shown in Figure 1 consists of three layers. The lower layer, which constitutes the ground plane, covers all the substrate and has a width of 6 cm and a length of 15 cm. The middle substrate, which is fr4 substrate has a dielectric constant $\varepsilon_r$ 4.4 and a height of 0.32cm. The upper layer, which is the patch, consists of a rectangle with a width of 3 cm and a length of 4 cm, joined with equilateral triangle of side 3cm. Inside the rectangular patch, ten rectangular slots, following Chebyshev distribution around a center rectangular slot, were inserted. According to Babinet's principle [9], the pattern of the slot was identical in shape to that of a dipole, except that the E and H fields were interchanged. Moreover, as was shown in [10], a Chebyshev distribution applied to an antenna array decreases side lobes and increases directivity. Accordingly, a slot array following the Chebyshev distribution inserted into a structure will increase the beam width and increase resonances. Also, inside the triangular patch, an equilateral triangular slot with a base 0.6 cm, was introduced with rectangular patch in which it can achieve beam width with required result.

<table>
<thead>
<tr>
<th>S. no</th>
<th>X</th>
<th>X-$\mu$</th>
<th>$P(X-\mu/\sigma)$=K</th>
<th>$1-1/K^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.35</td>
<td>0.25</td>
<td>1.44</td>
<td>0.52</td>
</tr>
<tr>
<td>2</td>
<td>0.26</td>
<td>0.16</td>
<td>0.941</td>
<td>0.06</td>
</tr>
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<td>0.09</td>
<td>0.5217</td>
<td>2.6</td>
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<tr>
<td>4</td>
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<td>0.04</td>
<td>0.23</td>
<td>17.9</td>
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<td>5</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
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<td>0.95</td>
<td>0.85</td>
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<td>-0.958</td>
</tr>
<tr>
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<td>0.101</td>
<td>0.01</td>
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<tr>
<td>8</td>
<td>0.3</td>
<td>0.1</td>
<td>-0.5217</td>
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</tr>
<tr>
<td>9</td>
<td>0.143</td>
<td>0.04</td>
<td>-0.23</td>
<td>-17.9</td>
</tr>
</tbody>
</table>

The heights of the slots can be adjusted by the listings of the above table where we can achieve desired multiband with required applications. Here the equilateral triangular slot and patch was introduced with rectangular patch in which it can achieve beam width with required result.

### 4. CONCERTO SOFTWARE

Antenna design in area of wireless communication is demanding simulation task. With the help of this software it can be used to design all complicated structures with less effort further the radiation into free space can be modeled accurately. It is a powerful and easy-to-use schematic design tool that radically speeds up the analysis, synthesis and optimization of complex structures and electromagnetic systems.

### 5. SIMULATION& DISCUSSION

The new antenna was designed using concerto software and discussion of results was explained below.

A parametric study and an optimization were done, in order to find the best feeding point of the structure. Several points were tested in order to get an overview of the defined functioning of the antenna, and to monitor the effect of both the triangular and the Chebyshev apertures, At first the feeding point was chosen close to triangular slot in which it observed that it is operated at 4.2 GHz which is used for military applications. In addition it can be operated at 3.5GHz Wi max applications and close to blue tooth operation 2.8GHz. The S11 parameter at 4.2GHz was observed as -11.657dB. The gain of antenna at particular location of feed point was observed as canonical shape as shown in fig6.

The feed point was moved near to chebyshev distributed slots, in which it is nearer to the radiating elements , it was observed that it can be operated at 5.8GHz.
WLAN applications, covering at 3.2 to 3.7GHz Wi max applications, The s11 parameter here observed was -21.644dB at 3.2GHz and -16dB at 5.8 GHz as shown in figure. The gain observed at 3.2GHz is 7.00 and at 5.8 GHz is 6.6 which can be acceptable result.

5.1 Return Loss

It is a measure of the reflected energy from a transmitted signal. It is commonly expressed in positive dB. The larger the value, the less energy that is reflected.

Fig 2: Measured s11 parameter when feed point was kept near the triangular slot with return loss below -10dB at four different frequencies

Fig 3: Measured s11 parameter when feed point was kept near the chebyshev’s distributed slots

5.2 Gain

The ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

Fig 4: Simulated results for gain at f=5.8GHz in concerto software

Fig 5: Simulated results for gain at f=3.2GHz in concerto software

Fig 6: Simulated result for gain =6at f=4.2GHz in concerto software
E-field distribution

Fig 7: Simulated result when only E-field acts on antenna

H-Field distribution:

Fig 8: Simulated result when only H-field acts on antenna

E&H field distribution:

Fig 9: Simulated result when both E &H field acts on antenna

Polar plot in theta direction at 0°:

Fig 10: Simulated result when Phi=-90 to 90 when theta=0(linear form)

Fig 11: Simulated result Phi=-90 to 90 when theta=0(polar plot)

Fig 12: Simulated result Phi=-90 to 90 when theta=90(linear form)
Polar plot in theta direction at 90°:

Fig 13: Simulated results Phi=-90 to 90 when theta=90 (polar plot)

6. APPLICATIONS

Numerous applications can subject for this newly designed antenna, it can be used for various broad band applications. By changing certain feed positions only we can achieve certain frequency of prescribed application. The s11 parameter for every resonant frequency are under -10dB. This new wideband operation of the antenna shares the presence of resonances at the wireless CCTV application at 2.8 GHz, and two other completely new applications

1. 4.2 GHz military application such as CMOV\CMOD down link application
2. 2.8 GHz: wireless CCTV and wireless video links, WLAN applications
3. 3.5 GHz: WLAN, Wi Max, wireless Wi Max, 802.16a applications.

7. CONCLUSION

A new multi-band antenna design has been presented. The design consists of joining a rectangular and equilateral triangular patch together in one patch, and inserting several forms of slots. The new idea behind this design also includes the insertion of rectangular slots following a Chebyshev distribution around a central rectangular slot, in addition to a triangular slot inserted into the triangle. The concept of inserting slot arrays following a known antenna-array distribution has proven to give remarkable functionality to an antenna. It causes it to be highly radiating in different frequency ranges, using only one single feed, represented by a 50 ohm SMA connector. The antenna has many applications, such as Wi-Fi, WIMAX, video wireless communication, and Bluetooth applications, in one single instrument, using this type of antenna

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