RELATIONSHIP FOR SLOTS WIDTH, ANTENNA DIRECTIVITY, AND THE 3*dB HPBW* OF AN RLSA ANTENNA AT 12.4GHz USING REGRESSION ANALYSIS

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ABSTRACT

The quest to optimize performance of the radial line slots array (RLSA) antenna continued to unfold. Attempt is made at studying slots width variation in radial line slot array antenna (RLSA) and its effect on the 3*dB* half power beam width (3dB *HPBW*) in this submission. It is aimed at formulating a polynomial equation that best describes the relationship between them. The polynomial equation in turn relates to the directivity of the RLSA antenna. The minimum number of slots in the first ring were restricted to (n_1) =12 and, (n_1) =14, this is used to manipulate slots concentration on the radiating surface. The restriction is owed to the fact that much cluster of slots in the first ring resulted to a deteriorating performance in terms of directivity values recorded from CST 2012 simulations, for the 12.4 GHz regression analysis in this study. Results obtained from the polynomial equation formed were compared with measured and simulated directivity values and showed good agreement.

Keywords: slots, RLSA antenna, beam squint, radial spacing, azimuthal spacing, return loss, gain, radiation characteristics.

INTRODUCTION

Numerical expression for directivity as it relates to measured and simulated *E* and *H* plane 3dB half power beam widths (3dB HPBW) has been formulated and reported in antennas by [1, 2]. It relates the *E* and *H* planes of the 3dB HPBW as inversely proportional to the antenna directivity, thus expressed as:

$$D_o = \frac{32,400}{\Theta_{Ed} * \Theta_{Hd}}$$
$$\Rightarrow 10\log_{10}(D_o) = dBi \quad (1)$$

Where

Θ_{Hd} = *H*- planes 3dB HPBW for (n) =12 and (n_1) = 14.

Θ_{Ed} = *E* - planes 3dB HPBW for (n) =12 and (n_1) = 14

This submission is aimed at formulating a polynomial relationship that relates slot width with 3dB HPBW and by extension; the directivity of the radial line slot array antenna (RLSA) operating at the Ku bands of frequencies; a resonant frequency of 12.4GHz is utilized. CST 2012 simulation of varying slot width is done and their corresponding *E* and *H* 3dB HPBW recorded. The number of slots pair in the first ring denoted by n_1=12, and n_1=14 were used to generate data, as slot width variation took range in values from $0.25 \leq w \leq 4.75$ respectively. The concentration of slots in the first ring denoted by n_1=12 and n_1=14 implies that subsequently ring numbers will conform proportionately as the radial distance increases from the center of the antenna dish to its full diameter (*d=600mm*), with *n* taking proportionate increment from (n_1:2:……n_n). The radial distance (S_ρ)= guard wavelength(λ_g) for a linearly polarized RLSA antenna as reported by [3, 4, 5, 6, 7, 8, 9]. Figure-1 is a schematic of the antenna and its associated parameters while Figure-2 shows a photograph of the antenna under test in the anechoic chamber.

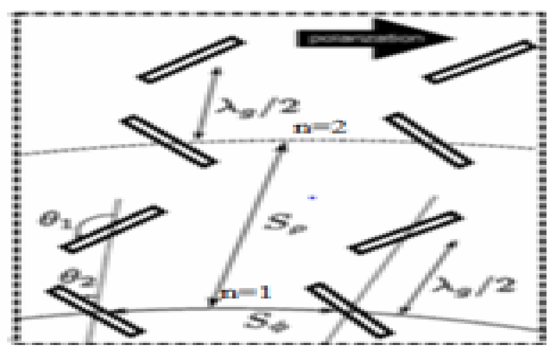

Figure-1. A cross section of the antenna schematics adapted from [6].

Figure-2. Prototype AUT in the scanning flange of the WCC Anechoic Chamber showing the mounted wave guide feed.

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The radiation slot length is given by this relationship as seen in [2].

$$L_{rad} = \left(5.8678 + 6.415 * 10^{-3} * \rho\right) * \frac{12.5 * 10^{9}}{f_{o}} \qquad (2)$$

Where

ρ is the antenna radius, and f_o is the resonant antenna frequency

CST, 2012 computations was carried out for a range in values of slots width using a 20 degree beam squinted RLSA design, from 0.25 ≤ w ≤ 4.75. Their radiation characteristics in terms of directivity were noted along with the *E* and *H* planes 3*dB HPBW*. Table I shows details of the computations from CST 2012 computations. Best computation results were used for prototype fabrication. Radiation measurements were carried out in the wireless communication center's anechoic chamber, details of the chamber cannot be accommodated in this submission due to formatting constraints.

Table-1. Shows varying slot widths directivity and *3dB HPBW* angles from CST 2012 simulations.

Slot width, w (mm)	**Dir** (*dBi*): **n=12**	Θ_H	Θ_E	**Dir** (d*Bi*): **n=14**	Θ_H	Θ_E
0.25	8.25	1.2	1.3	8.48	1.2	1.2
0.5	25.6	1.2	2.5	25.7	1.2	2.5
0.75	29	1.3	2.7	29/2	1.4	2.7
1	32.9	2.5	2.4	31.1	4.1	2.5
1.25	31.3	4	2.5	31.5	4	2.5
1.5	32.2	3.6	2.5	32.2	3.9	2.5
1.75	32.1	3.2	2.4	32.1	3.6	2.4
2	31.8	2.9	2.4	31.6	2.8	2.4
2.25	31.5	2.3	2.5	31.5	2.4	2.5
2.5	31.3	2.1	2.6	31.5	2.2	2.5
2.75	31.1	2.5	2.6	31.1	2.6	2.6
3	30.7	3.0	2.9	30.7	2.6	2.9
3.25	31.7	2.4	2.9	30.7	2.7	2.9
3.5	30.6	3.5	2.9	30.4	2.9	2.9
3.75	30.6	2.7	3.1	30.2	2.4	3.1
4	29.9	2.3	3.2	29.8	2.4	3.1
4.25	29.3	2.2	3.4	29.3	2.3	3.4
4.5	28.9	2.2	3.5	28.8	2.3	3.6
4.75	27.2	5.5	3.2	27.4	5.4	3.0

Dir = Directivity, Θ_H and Θ_E = 3*dB HPBW* in *E* and *H* planes

2. POLYNOMIAL FORMATION

Computations at 20 degree beam squinted RLSA were done to acquire data needed for the regression analysis, which gave the results in Table-1. For the 12.4GHz utilized in this study, with (n_1) =12 and (n_1) =14, the relationship between slots width (*w*) and the 3*dB HPBW* is graphically computed from the results in Table-1. Figures (3) and (4), are used for the regression analysis leading to the formation of the proposed polynomial equations

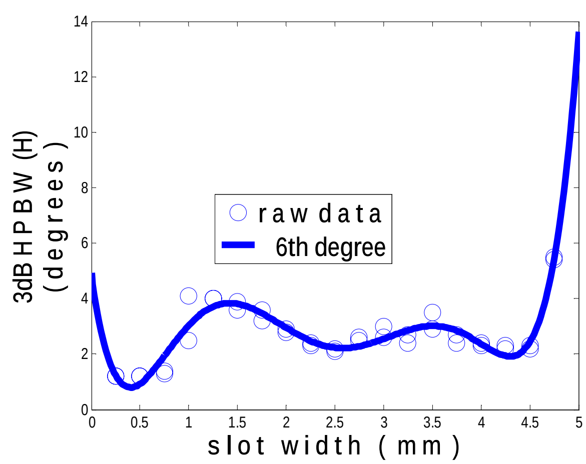

Figure-3. 6th order polynomial fitting for slots width versus 3*dB HPBW (*degrees) H-planes.

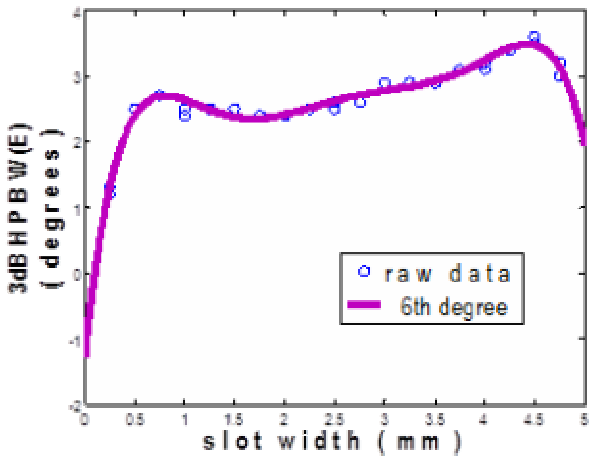

Figure-4. 6th order polynomial fitting for slots width versus 3dB HPBW (degrees) E-planes.

The *E* and *H*-planes 6th order polynomial equation of the RLSA antenna at 12.4GHz for a 600mm aperture diameter as obtained from the regression analysis in Figure (3) and (4) relates 3*dB HPBW* as a function of slot width and is thus stated mathematically as:

$$(\Theta_{Hd}) \oplus (\Theta_{Ed}) = f(w)$$
$$(\Theta_{Hd} * \Theta_{Ed}) = f(w)$$
$$\Rightarrow f(w) \Leftrightarrow (\Theta_{Hd} * \Theta_{Ed}) \quad (3)$$

$$\Theta_{Hd} = 0.19w^6 - 2.6w^5 + 16w^4 - 42w^3 + 52w^2 - 25w + 4.9 \quad (4)$$

$$\Theta_{Ed} = -0.041w^6 + 0.64w^5 - 4w^4 + 12w^3 - 20w^2 + 15w - 1.3 \quad (5)$$

Where

Θ_{Hd} = *H*- planes 3dB HPBW for (*n*) =12 and (*n*) = 14.

Θ_{Ed} = *E* - planes 3dB HPBW for (*n*) =12 and (*n*) = 14

W = slot width (*mm*).

Substituting (3) and (4) into (1), using the range in values of slots width (w), in (6), it becomes possible to obtain a corresponding antenna directivity numerically from MATLAB computations as seen;

$$w = (0.25 : 0.25 : 4.75); \quad (6)$$

$$D_o = \frac{32,400}{\Theta_{Ed} * \Theta_{Hd}}$$
$$\Rightarrow 10\log_{10}(D_o) = dBi \quad (1)$$

Substituting (3) in the denominator of (1) implies that (1) can conveniently be re-written as:

$$D_o = \frac{32,400}{f(w)} \quad (7)$$

The directivity values obtained in (*dBi*) relates the effect of varying slots width (*w*) to the 3*dB HPBW*. Thus, the polynomial equations for the 12.4GHz RLSA antennas, gives the RLSA designer the slots width that can results to best antenna performance in terms of directivity and the 3*dB HPBW*.

3. DISCUSSIONS

The peak value obtained at 45.45*dBi* suggests to the RLSA designer the optimal slot width required to give optimal antenna performance at 12.4GHz.The RLSA designer is thus guided in the selection of the best dielectric material as slow wave factor that will facilitates the attainment of this value obtained numerically.

A simple check

a) With (*w)* = 1; for n=12 Using 3*dB HPBW* from Table-1
$\Theta_{Hd} = 2.5\deg$ $\Theta_{Ed} = 2.4\deg$ Subsequent evaluations give 37.324(*dBi)*

b) With (w) = 1 for: n=14 using 3*dB HPBW* from Table-1, also
$\Theta_{Hd} = 4.1\deg$, $\Theta_{Ed} = 2.5\deg$ Subsequent evaluations give 34.998(*dBi*).

The directivity value obtained when *w*=1 using the proposed polynomial equations gave 34.53*dBi*. The 37.324*dBi*, 34.998 *dBi* and the 34.53*dBi* from the proposed polynomial are numerically obtained. The 32.9*dBi* is from CST 2012 simulations of the design.

4. CONCLUSIONS

The 34.53*dBi* in value of directivity with 1mm slot width for the 6th order polynomial is in close agreement with the 32.9*dBi* directivity value obtained from CST, 2012 computations at slot width 1*mm*. This authenticates the polynomial equations formed for the 12.4GHz. A difference in directivity value between the polynomial equations formed, with the simulated results at 1mm slot width is 1.63 *dBi*, this can be attributed to the choice of the dielectric material and other mismatch issues as the case might be.

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