Computational Analysis of Annular Ring Slot Loaded Microstrip Antenna

Padam Singh
ECE Department
J. P. Institute of Engineering & Technology.
Meerut.INDIA

Sanjeev Kumar
Instrumentation and Control Engineering
Department, Graphic Era University,
Dehradun.INDIA

ABSTRACT
This paper presents an investigation conducted on annular ring slot loaded microstrip antenna operating in triple band and it is found to exhibit frequency tunability with the slot angle. Return loss of the proposed antenna has been investigated as a function of slot angle θ with fixed coaxial feed location. It is found that the said parameter of antenna depends heavily on the slot angle θ. Resonant frequency and magnitude of return loss has also been investigated as a function of θ. The variation in resonant frequency for first, second and third resonance is (1.43GHz to 1.57GHz), (1.772GHz to 1.973GHz) and (2.557Ghz to 2.597GHz)and the variation in return loss is (-9.297dB to -1.75dB),(-21.15dB to-27.25 dB) and (-23.89dB to-26.83 dB) respectively. All simulations are carried out using Zeland IE3D software.

Keywords
Slot angle, Annular Ring Slot, return loss, resonant frequency, triple band..

1. INTRODUCTION
Multi-band antennas can be used simultaneously in many research projects. Recent interest has developed in radiator etched on electrically thick substrates as these antennas are used for high frequency applications. However, microstrip antennas inherently have narrow bandwidth [1]. In many cases, their increased impedance bandwidth is also paid for poorer radiation characteristics. Ring slot antennas have been of great interest to many researches and engineers and many related studies have been reported in the open literature. Many characteristics of the ring-slot antenna have been demonstrated [2, 3, and 4].

The annular ring and annular ring slot is one of the simplest structures and has contributed excellent results in RF and millimetre-wave applications [5].This paper proposes annular-ring slot loaded antennas operating in triple band. It is observed that the slot actually shifts the resonance frequency towards left side of the resonant band and a meaningful variation in return loss is also noticed [10]. Therefore, the design discussed in this paper can be known as frequency reconfigurable design. By varying the slot angle a desired resonant frequency can be obtained.

2. ANNULAR RING SLOT ANTENNA CONFIGURATIONS AND OPERATIONS
For the proposed annular-slot antenna, the first mode is mainly determined by the circumference of the inner and outer slot-rings (in case of multiple slots), and the second mode is determined by the outer circumference. The annular-slot widths and the microstrip feed line parameters also have a significant effect on performance. An approximation is given by [6]:

$$\lambda_{gs} = 2\pi R \quad (1)$$

where R is the radius of annular-slot, λ_{gs} is slot guided wavelength where:

$$\lambda_{gs} = \lambda_o\{1.045 - 0.365\ln\varepsilon_r + \frac{6.3(\mathrm{W/h})\varepsilon_r^{0.945}}{(238.64 + 100W/h)} - [0.148 - \frac{8.81(\varepsilon_r + 0.95)}{100\varepsilon_r}]\ln(h/\lambda_o) \quad (2)$$

The slot antenna is tightly coupled to the coaxial probe and hence, the feed line parameters are key factors. For a single ring, when the mean circumference of the ring is equal to an integral multiple of the guided wavelength, the resonance is established and expressed as [7]:

$$l = 2\pi R = n\lambda_{gs}, \text{ for } n = 1, 2, 3 \ldots \quad (3)$$

Where l is the mean circumference of the ring, λ_{gs} is the guided wavelength. The guided wavelength is related to the effective dielectric constant as:

$$\lambda_{gs} = \frac{\lambda_o}{\sqrt{\varepsilon_{eff}}} \quad (4)$$

Where λ_o is the wavelength in free space, ε_{eff} is the Effective dielectric constant. Thus, the resonant frequencies can be represented as:

$$f_n = \frac{nc_o}{l\sqrt{\varepsilon_{eff}}}, \quad (5)$$

for mode n=1, 2, 3 …where c is the speed of light. Equation 3 is applicable for multiple slot ring structure. This equation holds good for the analysis of slot ring (multiple ring) for multiband operation.

3. ANTENNA GEOMETRY AND DESIGN
The geometry of the proposed antenna is shown in figure.1.The ground plane lies at the bottom side of the microstrip antenna with a very compact size of 36mm×46.5mm×1.6mm.The radiation elements of the proposed antenna consist of an annular ring slot, operating approximately at in triple band. The resonant frequencies and return losses as a function of slot angle θ are given in table 1.

The design frequency is taken as 2.0 GHz. The antenna is proposed to design on a glass epoxy material with dielectric constant 4.2 and the thickness equal to 1.6mm. All the simulations are carried out using Zeland IE3D software (ver.12). The other parameters such as ground plane length and width, Length extension etc. are calculated for ε_r=4.2 and h=1.6mm using [8]. For a rectangular microstrip antenna (without slot) the resonant frequency is given as [9]:

$$f_r = \frac{c}{2(L+\Delta L)\sqrt{\varepsilon_r}} \quad (6)$$

Where ΔL is the length extension. An annular-ring slot is loaded on the patch. The inner and outer radius of the antenna are 4mm and 7mm respectively. The antennas are operating in triple band. The antenna is fed by a coaxial probe at (31,15). The centre of the patch is taken as (21.75, 28) taking the consideration of dimension of ground plane. Nine different geometries of the proposed ring slot microstrip antenna are considered. The value of θ is a variable ranging from 0 degree to 360 degree with a step size of 45 degree as shown in figure 1.

4. SIMULATION AND RESULTS

The antenna is simulated for return loss only. The simulated values (selected) are shown in table I. It is clear from table I that the antenna is operating in triple band. Figures 2, 3 and 4 are based on table I which shows the resonance of antenna in first, second and third resonance band respectively. The substrate with dielectric constant ε_r = 4.2 and thickness h = 1.6 mm is used. A 50Ω coaxial probe is directly feeds at point (31,15.) The centre of the patch is taken as (21.75, 28) taking the consideration of dimension of ground plane. Figure 2 shows the simulated return loss of the proposed slot antenna.

4.1 Resonant frequencies of loaded slot

The antennas were simulated for return loss using Zeland IE3D software. A careful simulation study of resonant frequency, bandwidth and return loss of the antenna was

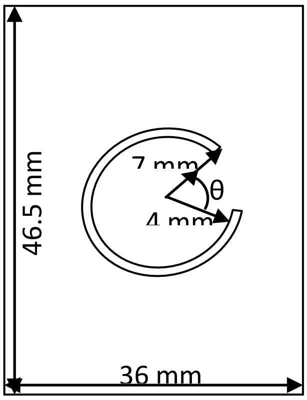

Figure.1: annular ring slot antenna with W=46.5mm, L=36mm, inner radius=4mm, outer radius=7mm, h=1.6mm, ε_r=4.2probe at (31,15) with centre at (21.75,28).The value of θ is ranging from 0 to 360 degree.

undertaken and the results of return loss are presented. The radiation elements of the proposed antenna consist of an annular ring slot, operating in triple band. It is clear from table I that that the variation is resonance frequency is 1.43GHz to 1.57GHz for first resonance band, 1.772GHz to 1.937GHz for second resonance band and 2.537GHz to 2.597GHz for third resonance band. Figure 2, 3 and 4 shows the variation in frequency for first, second and third resonance band. The following parameters have been studied.

(i) Dependence of resonant frequencies on slot angle
(ii) Dependence of return loss on slot angle.

Table 2:Resonance frequency w.r.t slot angle (θ)

Slot Angle(θ) (Degree)	First Resonance Frequency	Second Resonance Frequency	Third Resonance Frequency
0	1.43	1.812	2.557
45	1.45	1.772	2.537
90	1.45	1.832	2.557
135	1.45	1.893	2.557
180	1.47	1.933	2.557
225	1.51	1.953	2.577
270	1.55	1.953	2.577
315	1.57	1.973	2.597
360	1.57	1.973	2.577

4.2 Dependence of resonant frequencies on slot angle

The dependence of resonant frequency on the slot angle is shown in table II and figure 5. It is thus clear that a meaningful shift in resonance frequency of each resonance band is noticed therefore a range of frequency tunability is achieved. The value of resonance frequency shifts towards right for all operating bands. However, the first or fundamental resonance band exhibits a small variation but, second and third resonance shows a meaningful variation.

4.3 Dependence of return loss on slot angle

The dependence of resonant frequency on the slot angle is shown in table III and figure 6. It is thus clear that a meaningful shift in return loss of each resonance is noticed. It is also clear that there is a little variation in the first or fundamental resonance; second resonance shows a very good property of tunability while third resonance shows very interesting results In third resonance the graph shows a sinusoidal like behavior. The value of return loss change at each value of the slot angle (45 degree step size).

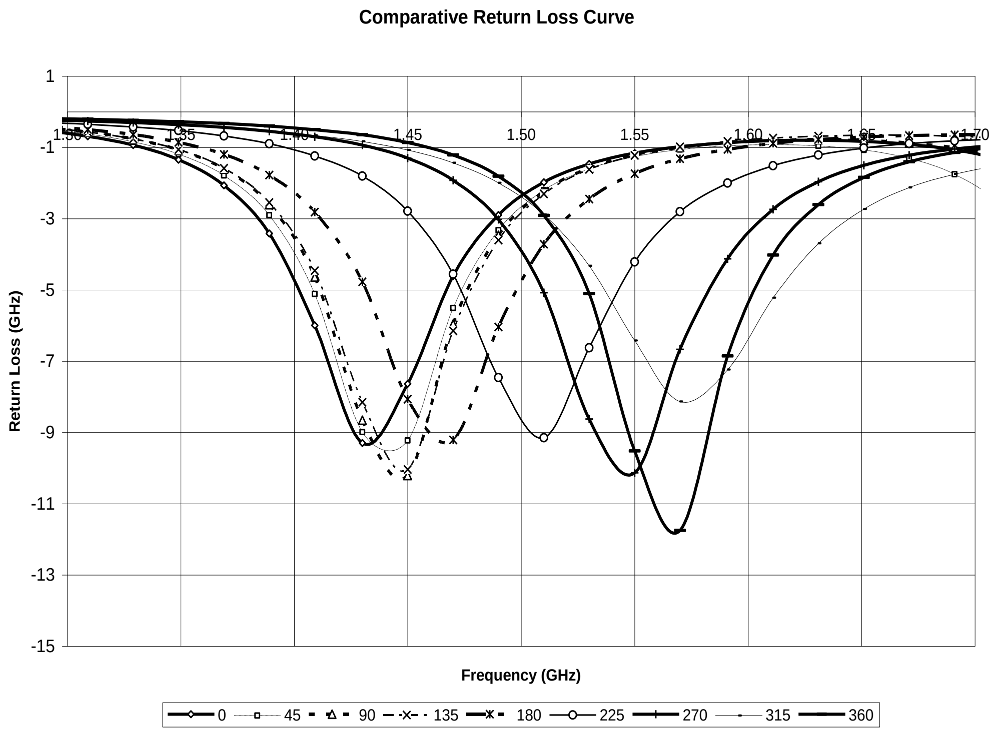

Figure.2: Comparative Return loss curve for the proposed antenna operating in first resonance band for different values of θ.

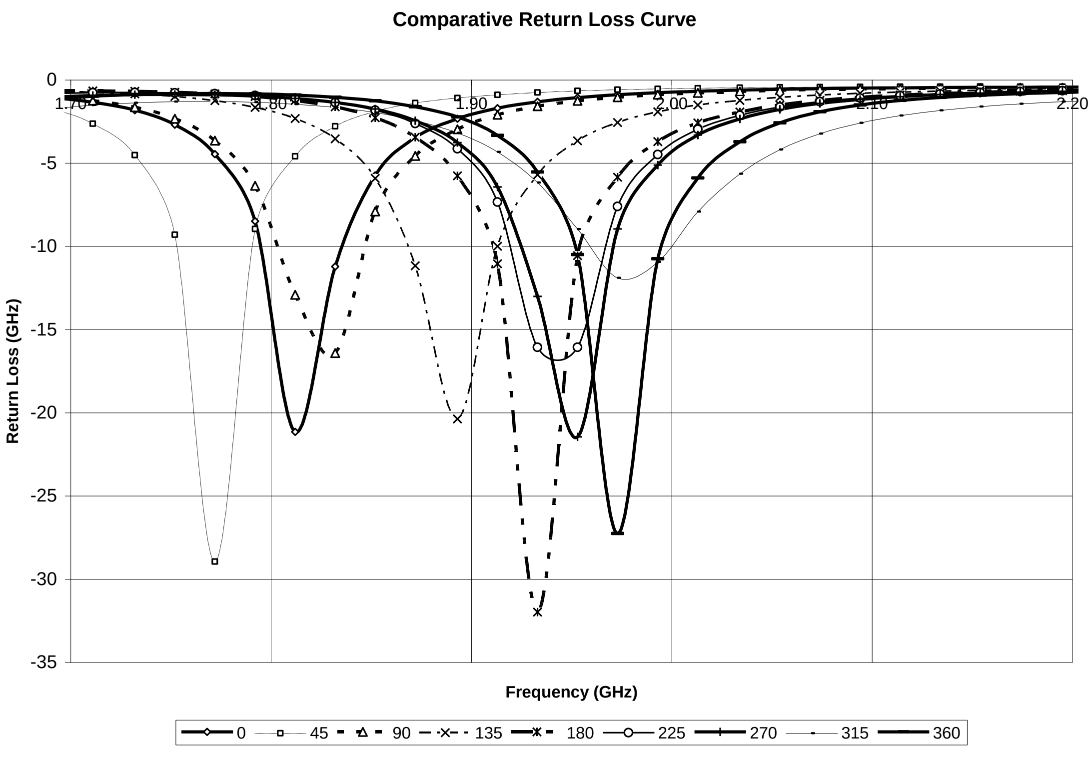

Figure.3: Comparative Return loss curve for the proposed antenna operating in second resonance band for different values of θ

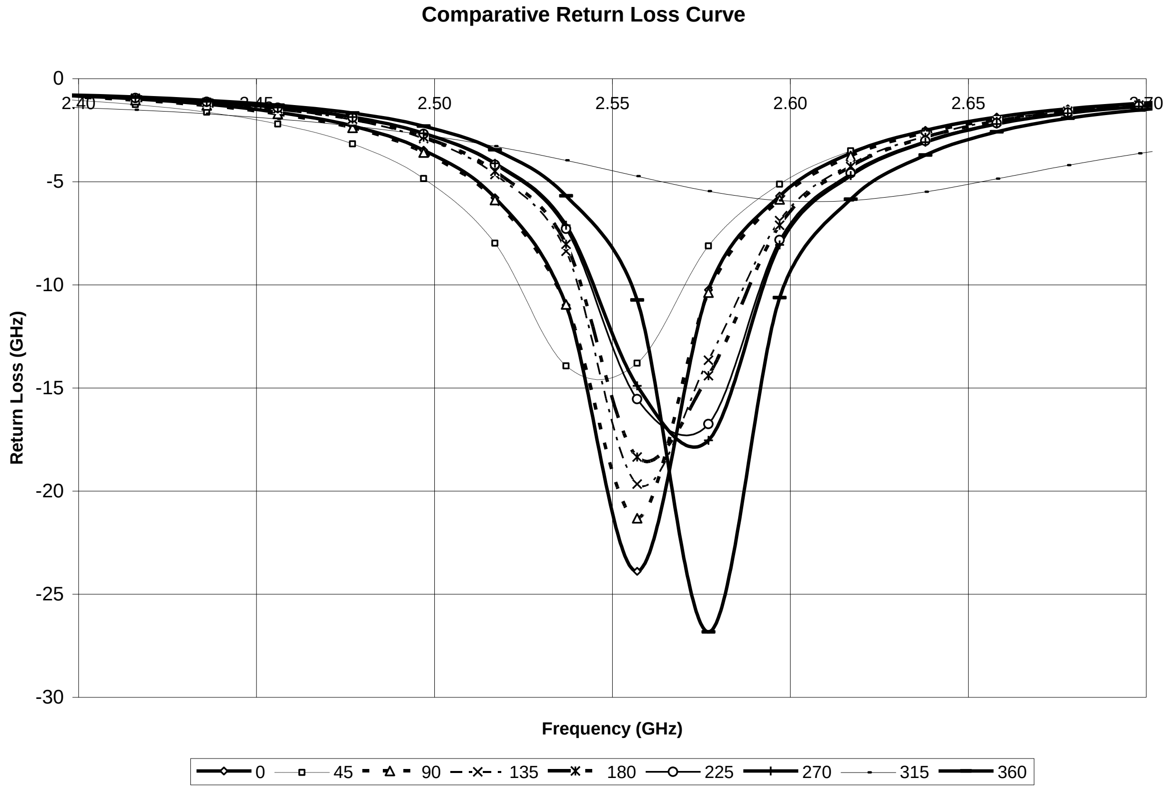

Figure.4: Comparative Return loss curve for the proposed antenna operating in third resonance band for different values of θ

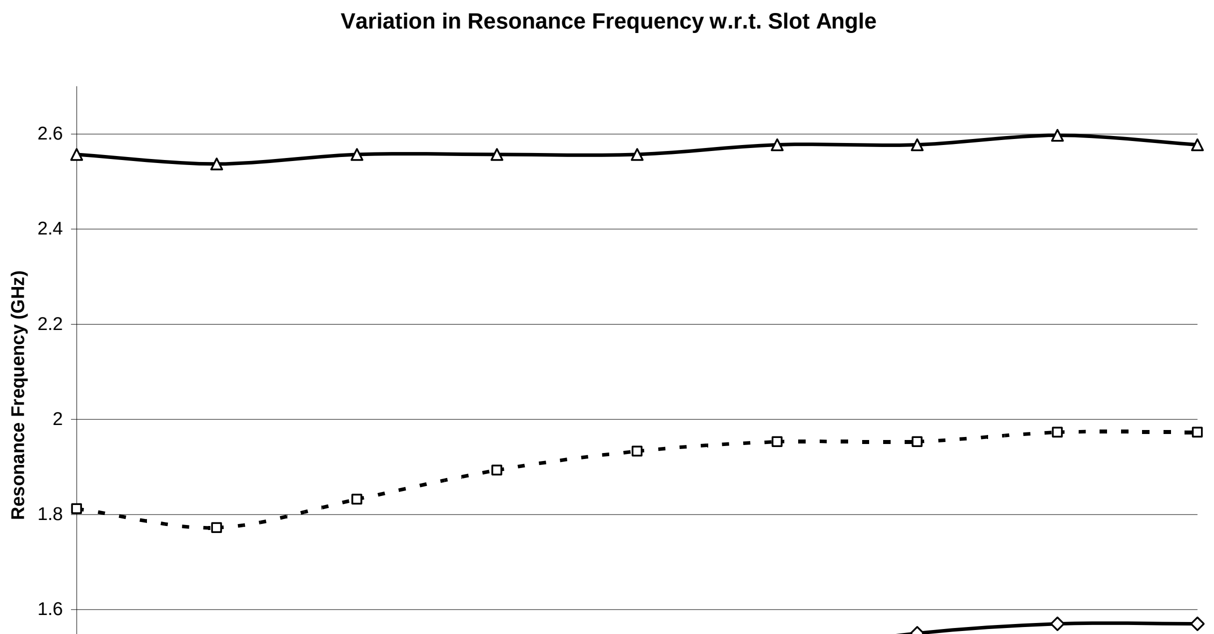

Figure.5: Variation in resonance frequency of first, second and third resonance w.r.t slot angle θ

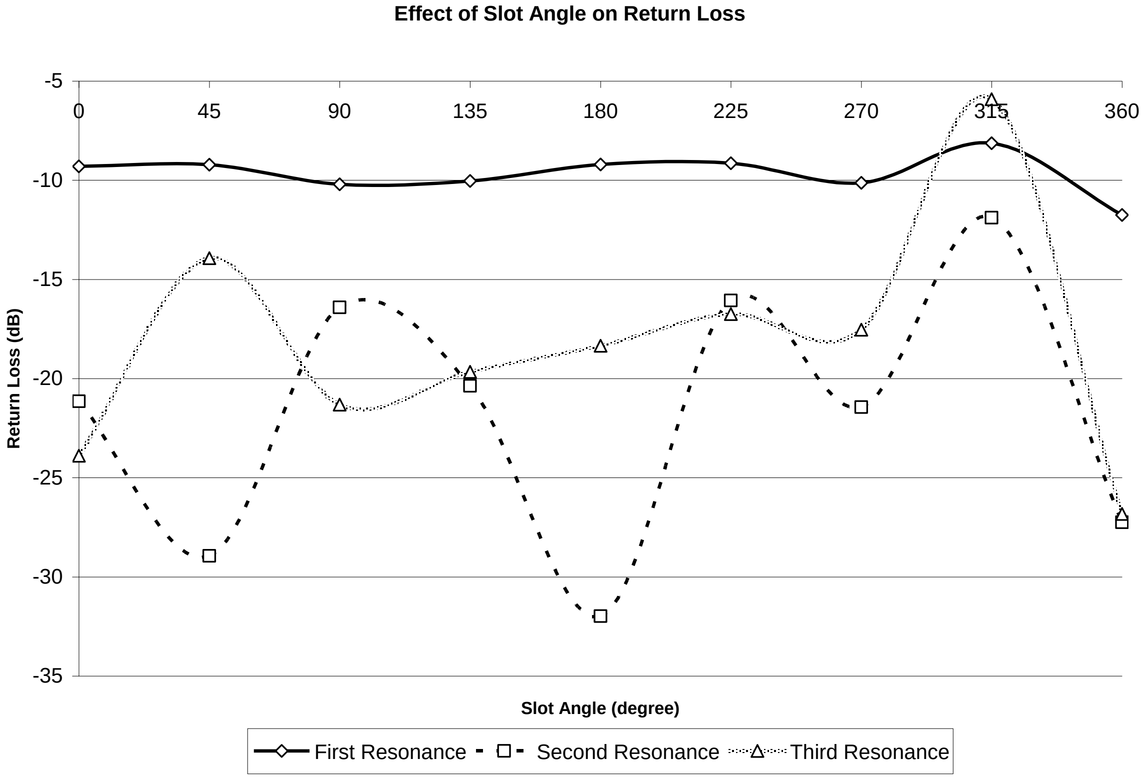

Figure.6: Variation in return loss of first, second and third resonance w.r.t slot angle θ

Table 3:Return loss w.r.t slot angle (θ)

Slot Angle(θ) (Degree)	RL Value (First)	RL Value (Second)	RL Value (Third)
0	-9.297	-21.15	-23.89
45	-9.222	-28.94	-13.93
90	-10.21	-16.41	-21.32
135	-10.04	-20.37	-19.66
180	-9.206	-31.98	-18.35
225	-9.145	-16.07	-16.75
270	-10.13	-21.44	-17.54
315	-8.131	-11.89	-5.916
360	-11.75	-27.25	-26.83

5. CONCLUSION

A new technique for designing triple band reconfigurable slot antenna is proposed. The technique is successfully applied to design a triple band slot antenna with consistent return loss at triple band and over the entire frequency range of antenna (specially 0 to 3 GHz). Simulation of antenna indicate that maximum variation noticed in resonance frequency is (1.43GHz to 1.57GHz), (1.772GHz to 1.973GHz) and (2.557Ghz to 2.597GHz) for first, second and third resonance respectively. Return loss of the proposed antenna has been investigated as a function of slot angle θ with fixed coaxial feed location. It is found that the said parameter of antenna depends heavily on the slot angle θ. The variation in return loss is (-9.297dB to -1.75dB),(-21.15dB to-27.25 dB) and (-23.89dB to-26.83 dB) respectively. Thus a wide range of frequency and return loss tunability is achieved.

6. REFERENCES

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Table 1: Return loss for different slot angle and resonance frequency

Slot Angle→ / **Frequency (GHz) ↓**	**0**	**45**	**90**	**135**	**180**	**225**	**270**	**315**	**360**
1.43	**-9.297**	-8.987	-8.658	-8.154	-4.771	-1.804	-0.9343	-0.8306	-0.6446
1.45	-7.636	**-9.222**	**-10.21**	**-10.04**	-8.066	-2.787	-1.303	-1.073	-0.8626
1.47	-4.604	-5.506	-5.957	-6.149	**-9.206**	-4.558	-1.921	-1.434	-1.212
1.51	-1.98	-2.204	-2.231	-2.308	-3.716	**-9.145**	-5.079	-2.887	-2.909
1.55	-1.161	-1.257	-1.215	-1.222	-1.74	-4.214	**-10.13**	-6.423	-9.519
1.57	-0.9761	-1.061	-0.998	-0.9816	-1.319	-2.806	-6.665	**-8.131**	**-11.75**
1.772	-4.459	**-28.94**	-3.641	-1.244	-0.8367	-0.8293	-0.8942	-1.293	-0.8145
1.812	**-21.15**	-4.59	-12.91	-2.323	-1.228	-1.093	-1.109	-1.457	-0.9106
1.832	-11.21	-2.784	**-16.41**	-3.54	-1.615	-1.364	-1.348	-1.653	-1.039
1.893	-2.328	-1.089	-2.964	**-20.37**	-5.76	-4.139	-3.764	-3.174	-2.224
1.933	-1.309	-0.757	-1.581	-5.696	**-31.98**	-16.06	-13.01	-6.167	-5.531
1.953	-1.059	-0.6612	-1.254	-3.662	-10.55	**-16.07**	**-21.44**	-8.962	-10.5
1.973	-0.8893	-0.5909	-1.035	-2.562	-5.841	-7.603	-8.948	**-11.89**	**-27.25**
2.537	-10.98	**-13.93**	-10.95	-8.369	-8.03	-7.287	-7.107	-3.961	-5.684
2.557	**-23.89**	-13.8	**-21.32**	**-19.66**	**-18.35**	-15.54	-14.9	-4.73	-10.74
2.577	-10.25	-8.111	-10.38	-13.66	-14.41	**-16.75**	**-17.54**	-5.458	**-26.83**
2.597	-5.695	-5.125	-5.864	-6.881	-7.11	-7.823	-8.062	**-5.916**	-10.62