6.5 The Simulation Results

HTS microstrip is characterized by some features affecting the quality factor:

1-The non-linear dielectric substrate thickness, d

2-The conductive strip (line on substrate) thickness, t

3-The dc electric field applied, E

6.6 Proposed Approach Enhancement Results of Quality Factor:

Enhancement Results of Quality Factor by The effect results of changing these factors has been presented and simulated. The basic factor for tuning the quality is to reduce the dimension and the electric field or by deposition The material of nonlinear dielectric substrate strontium titanate ($SrTiO_3$) thin films were prepared by an off-axis pulsed laser deposition technique on neodymium gallate ($NdGaO_3$) substrates held at temperature of 820 ∘c.

6-6-1 The effect results of changing these factors has been presented and simulated. The basic factor for tuning the quality is to reduce the dimension and the electric field. [STO], Using the Proposed Approach in Verifying Published Results.

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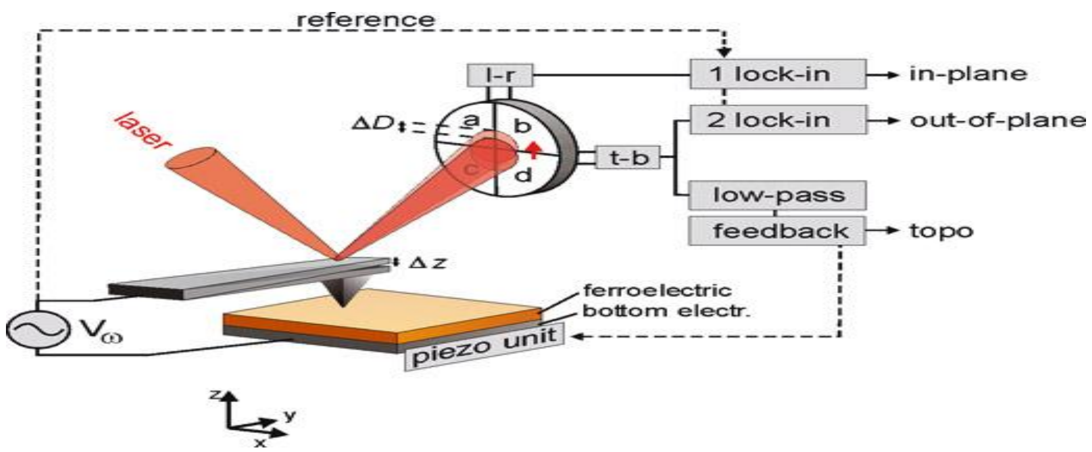


Fig 6.17 the geometrical change of dimension rectangular microstrip.

First, the results in case of changing the thickness of line (YBCO) with the thickness of the non-linear dielectric substrate (STO) with no dc electric field, to study the effects of both thickness on the value of quality factor, and obtain the maximum Q at the smallest dimension and best performance of microstrip, with a DC electric field up to +/- 10 V/µm, at 78◦K. The thickness of line (t1) is changed from 0.3 µm to 2 µm [46] and the thickness of substrate (d) is changed from 254 µm to 1590 µm [25,51].

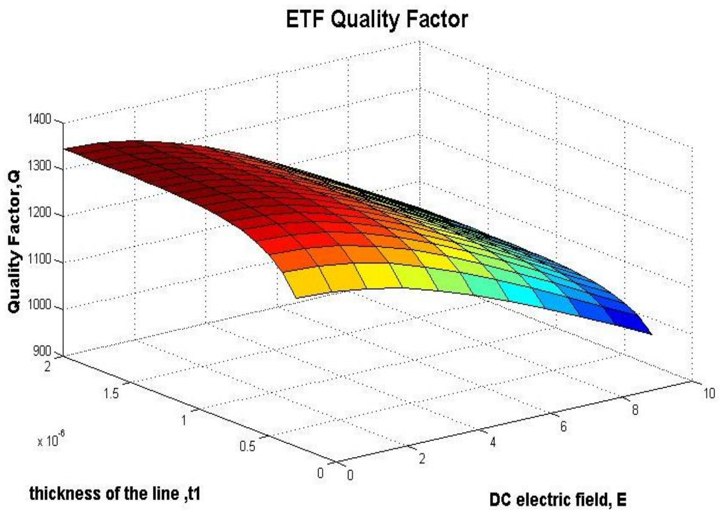


Fig 6-18 Changing thickness of the line t1 and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant thickness of substrate, d =254 µm, T=78K.

E(KV/Cm)	**0**			2	4	6	8	10
t1 (µm)	**0.5**			1.3	1.6	1.8	1.7	1.8
Q	**1290**			1327	1279	1209	1127	1043
t1 (µm)	**2**	**0.7**	**0.3**	0.3	0.5	0.5	0.5	0.4
Q	**1345**	**1307**	**1219**	1205	1230	1165	1089	993

Table 6-3 Changing thickness of the line t1 and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant thickness of substrate, d =254 µm, T=78K.

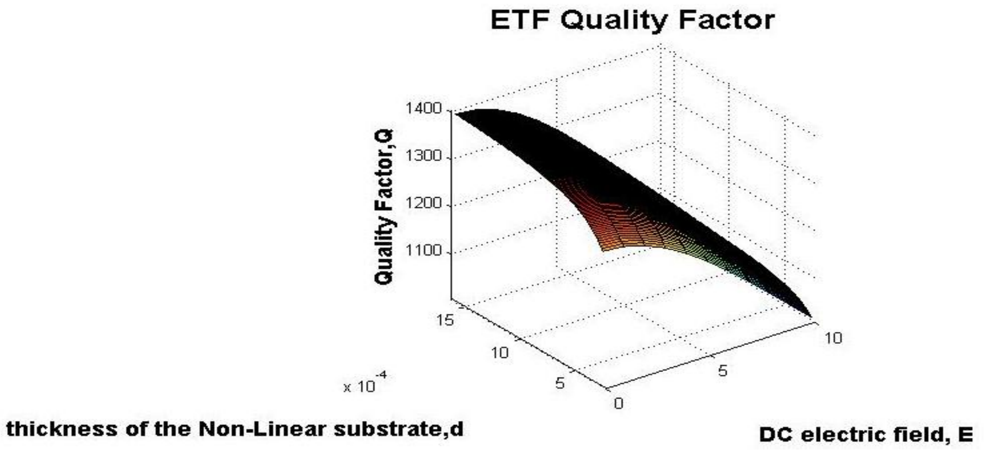


Fig 6-19 Changing thickness of substrate d and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant thickness of line t1=0.5 µm ,T=78K.

E(KV/cm)	**0**	2	4	6	8	10
d (µm)	**254**	264	264	254	264	254
Q	**1290**	1278	1234	1089	1092	1010
d (µm)	1574	1524	1384	1434	864	564
Q	1400	1380	1326	1251	1153	1052

Table 6-4 Changing thickness of substrate d and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant thickness of line t1=0.5 µm ,T=78K.

In case of ETF at Fig (6-18) and Table (6-2), Q_E value increases with decreasing the dc electric field and increasing the substrate thickness. The maximum result of Q_E value is achieved with no dc electric field in the recently published results. In the proposed algorithm the simulation verifies the results published and find that the best quality factor achieved is Q_E ≈1290, with dc electric field is at value of E>0 at t1=0.5 µm, and increased with E<2 KV/cm. In case of ETF, the maximum results of Q_E value published at T=78◦ K and E=0 KV/cm, the results in case of changing thicknesses of line from 0.5µm to 2µm, with change dc electric field of 0<E<10 KV/cm, the maximum results of Q_E value at T=78◦ K and E=0KV/cm, is about 1300 at t1=1.3 μm and d=254 μm, E=2 KV/cm. It is clear from the fig that increasing thicknesses of substrate line increases the Q_E value, and the smallest dimensions to obtain t1=0.3μm at E=0 KV/cm given Q_E =1219 .The best Q_E about 1300, t1=0.5 μm, d=254 μm and E< 2 KV/cm. In second fig 6-19 and Table (6-3), Q_E value increases with decreasing the dc electric field and increasing the thickness of substrate. The maximum result of Q_E value is achieved with no dc electric field in the recently published results. In the proposed algorithm the simulation verifies the results published and find that the best quality factor achieved is Q_E ≈1290, with dc electric field is at value of E=0 KV/cm at d=254μm, and increased with E<2 KV/cm. In case of ETF, the maximum results of Q_E value published at T=78◦ K and E=0 KV/cm, the results in case of changing thicknesses of substrate line from 254 μm to 1590μm, with change dc electric field of 0<E<10 KV/cm, the maximum results of Q_E value published at T=78 K and E=0 KV/cm, is about 1400 at d=1574 μm. The smallest dimensions to obtain d=284μm at E=0 KV/cm given Q_E =1303 It is clear from the figure that increasing thicknesses of substrate line increases the Q_E value, and the smallest dimensions to obtain the best Q_E about 1300 ,254<d<264 μm and t1=0.5 μm and E<2 KV/cm.

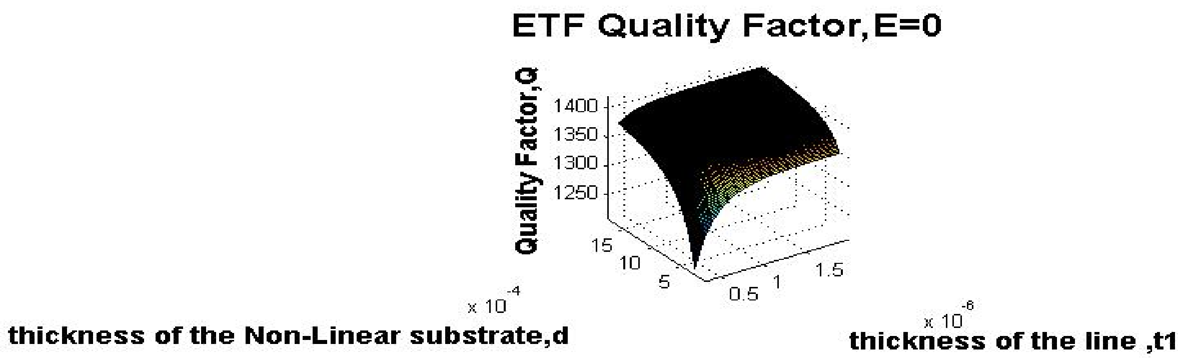


Fig 6-20 Changing thickness of the substrate d with the thickness of line t1 dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant E=0KV/cm, T=78◦K.

Q	**1290**	1396	1361	1350	1370	1400	1410
d µm	**254**	264	464	374	374	1399	1394
t1 µm	**0.5**	1.6	0.6	1.2	2	0.5	1.9

Table 6-5 Changing thickness of the substrate d with the thickness of line t1 dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO at constant E=0KV/cm, T=78°K.

In case of ETF in fig 6-20 and Table 6-3 ,*QE* value increases with increasing the substrate thickness line d and increasing the thickness of line t1.The maximum result of *QE* value is achieved about 1400 with no dc electric field , t1=1.6 µm and d=264 µm.

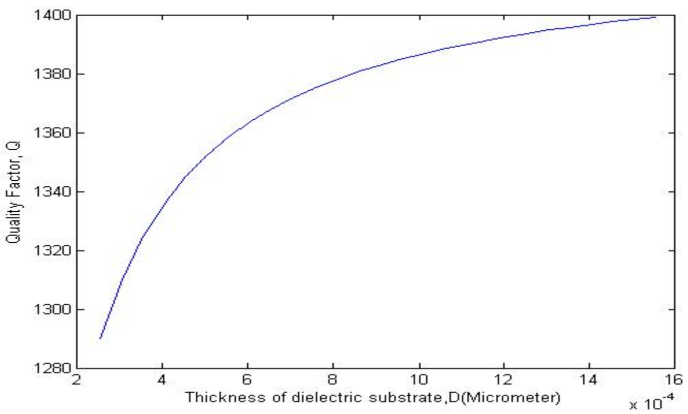


Fig 6-21 Changing thickness of the substrate d with quality factor of (ETF) at thickness of the line t1=0.5 µm, of a YBCO microstrip resonator on a non-linear substrate of STO at constant E=0KV/cm, T=78K.

d (µm)	254	304	354	404	**504**	554	604
QE	1290	1310	1325	1345	**1352**	1359	1364

Table 6-6 Changing thickness of the substrate d with quality factor of (ETF) at thickness of the line t1=0.5 µm, of an YBCO microstrip resonator on a non-linear substrate of STO at constant E=0KV/cm, T=78K.

When the draw on two dimensions the same result at three dimensions at Fig 6-16, The maximum result of Q_E value is achieved about 1400 with no dc electric field , t1=0.5µm and d=504 µm.

6.6.2 The material of nonlinear dielectric substrate strontium titanate (SrTiO3 or STO) thin films were prepared by an off-axis pulsed laser deposition technique on neodymium gallate (NdGaO3 or NGO) substrates held at temperature of 820 ∘c:

UHV plasma jet system for deposition of thin films

Fig 6-22 UHV Plasma jet system for deposition of thin films.

The dielectric responses were measured at 10 GHz, and from 300◦ K to 4 ◦K. the highest change in the dielectric constant with an electric field of 4 Vμlm. STO thin films show a dielectric constant close to 300 at room temperature, which typically reaches a maximum between 1000 and 10,000 in the 30–100◦ K range and then decreases steadily. STO thin films also show higher dielectric loss, typically in the range of 10^{-2} to 10^{-4} with a DC electric field up to +/- 4 V/um, at 78◦K [47,52]. The thickness of line, t1, is changed from 0.3 μm to 2 μm [46], and the thickness of substrate, d, is changed from 2.2 cm to 3.5 cm. [52]

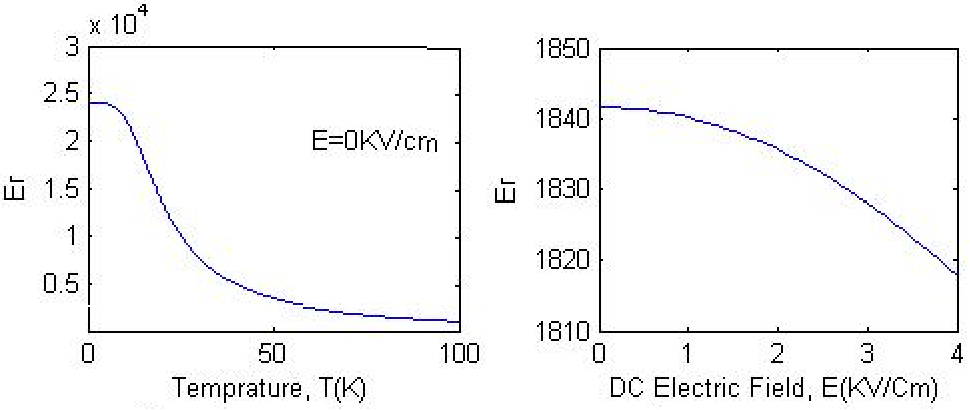


Fig. 6-23 Dependence of relative permittivity of STO/NGO on the temperature, and dc electric field at 10 GHz, 78K.

From Fig6-23, When relative permittivity of STO/NGO change with temperature, the value of relative permittivity equal $2.433*10^{4}$ at zero temperature and equal 1842 at 78K. When relative permittivity of STO/NGO change with DC Electric Field, The value of relative permittivity equal 1842 at zero and 1818 at DC Electric Field equal 4 KV/Cm.

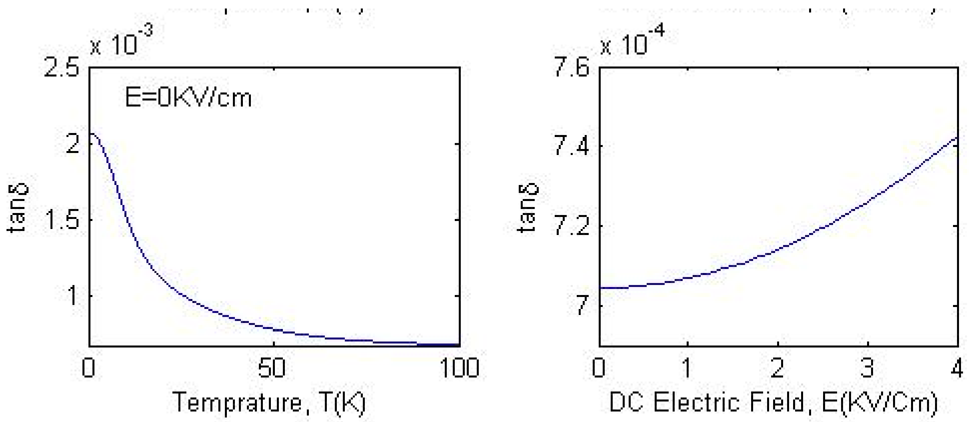
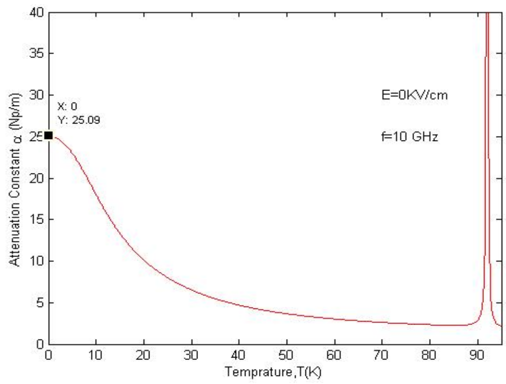


Fig 6-24 Dependence of tangent loss tangent of STO/NGO on temperature and dc electric field at 10 GHz, 78K.

From Fig 6-24, when tangent loss tangent of STO/NGO change with temperature, the value of tangent loss tangent equal 0. $2075*10^{-5}$ at zero temperature and equal $0.7044*10^{-6}$ at 78K. When tangent loss tangent of STO/NGO change with DC Electric Field, The value of tangent loss tangent equal 0.7044*10^{-7} at zero DC Electric Field and 0.7426*10^{-8} at DC Electric Field equal 4 KV/Cm



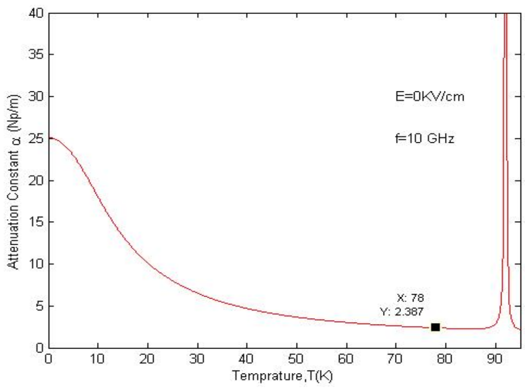


Fig 6-25. Calculated attenuation constant of a YBCO line on the non-linear substrate of STO /NGO as a function of temperature at 10 GHz. The solid lines are calculated from the ETF model, while the broken lines are from the CTF model.

From Fig6-25, A maximum value of α at T = 0◦K is about 25.09 (Np/m). The Q -value monotonically decreases with the increasing temperature. The value of Q occurs at T=78◦K, α =2.387 (Np/m).

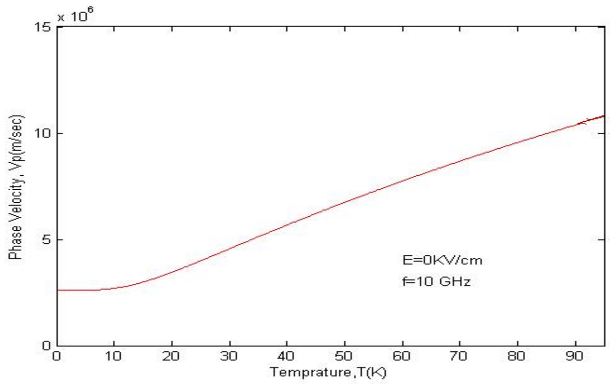


Fig 6-26. Computed phase velocity of a YBCO line on the non-linear substrate of STO/NGO as a function of temperature at 10 GHz. The solid lines are calculated from the ETF model, while the broken lines are from the CTF model.

From Fig6-26, A maximum value of v_p at T =0K is about 2.598x10^{-6}(m/sec). The value of v_p monotonically increasing with the increasing temperature. The value of v_p occurs at T=78◦K, v_p=9.38x10^{-6} (m/sec).

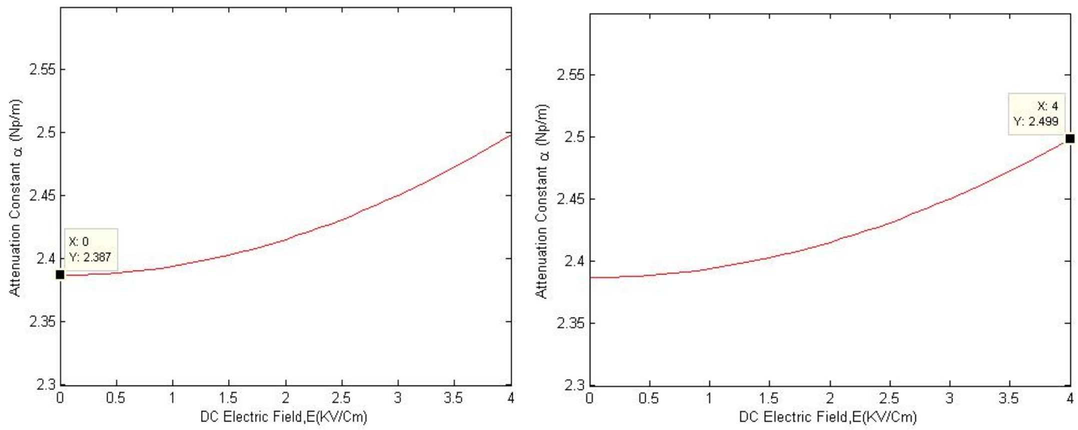


Fig 6-27. Computed attenuation constant of a YBCO line on the non-linear substrate of STO/NGO as a function of dc electric field at 10 GHz and 78 K. (ETF).

From Fig(6-27), A maximum value of α at E= 0 KV/cm is about 2.397 (Np/m). The value of v_p monotonically increasing with the increasing temperature. The value of v_p occurs at E=4KV/cm, α =2.499 (Np/m).

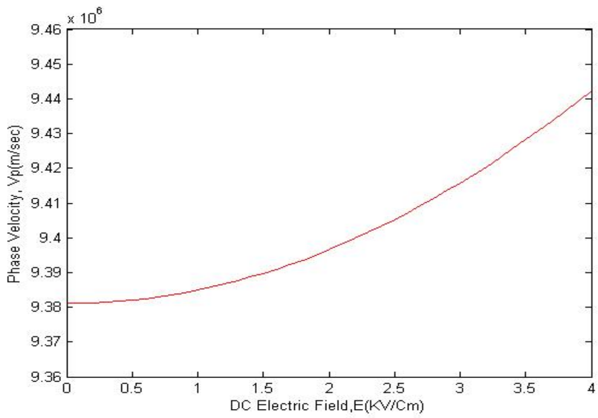


Fig 6-28 Computed phase velocity of a YBCO line on the non-linear substrate of STO/NGO as a function of dc electric field at 10 GHz and 78K. The solid lines are calculated from the ETF model.

From Fig6-28, A maximum value of v_p at E= 0 KV/cm, is about 9.38*10^6 (m/sec).The value of v_p monotonically increasing with the increasing temperature. The value of v_p occurs at E=4KV/cm, v_p =9.47*10^6 (m/sec).

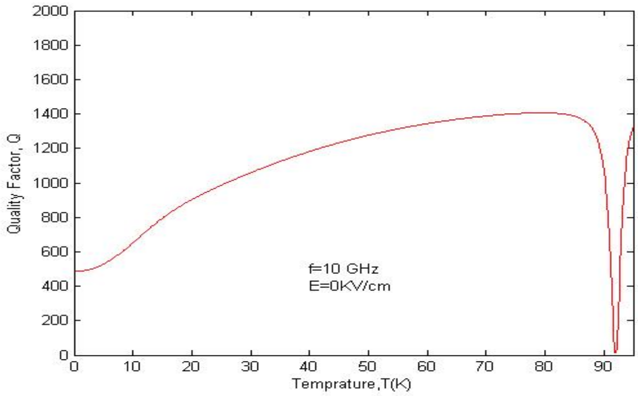


Fig 6-29 Computed temperature dependence of quality factor, of a YBCO microstrip resonator on the substrate of STO/NGO. The loss tangent is incorporated in the calculation .78K

T (K)	60	67	70	78	80
Q	1344	1380	1388	1406	1405

Table6-7 Computed temperature dependence of quality factor, of a YBCO microstrip resonator on the substrate of STO/NGO.

From Fig6-29, a maximum value of Q and is attained at temperatures below T_c and drops sharply near T_c. The Q -value at T = 0◦K is about 485.2.

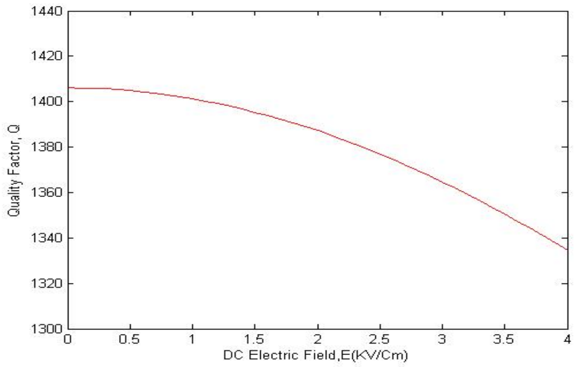


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Fig 6-30.Computed dc electric field dependence of quality factor, of a YBCO microstrip resonator on the substrate of STO/NGO. The loss tangent is considered in the Calculation at 78k

E(KV/cm)	0	2	4
Q	1406	1387	1335

Fig 6-8Computed dc electric field dependence of quality factor, of a YBCO microstrip resonator on the substrate of STO/NGO.

From Fig6-30, the Q -value monotonically decreases with the increasing dc electric field. The maximum value of Q occurs at E =0, T=78◦K, Q =1406, and at E=4KV/cm the value of Q about 1335.

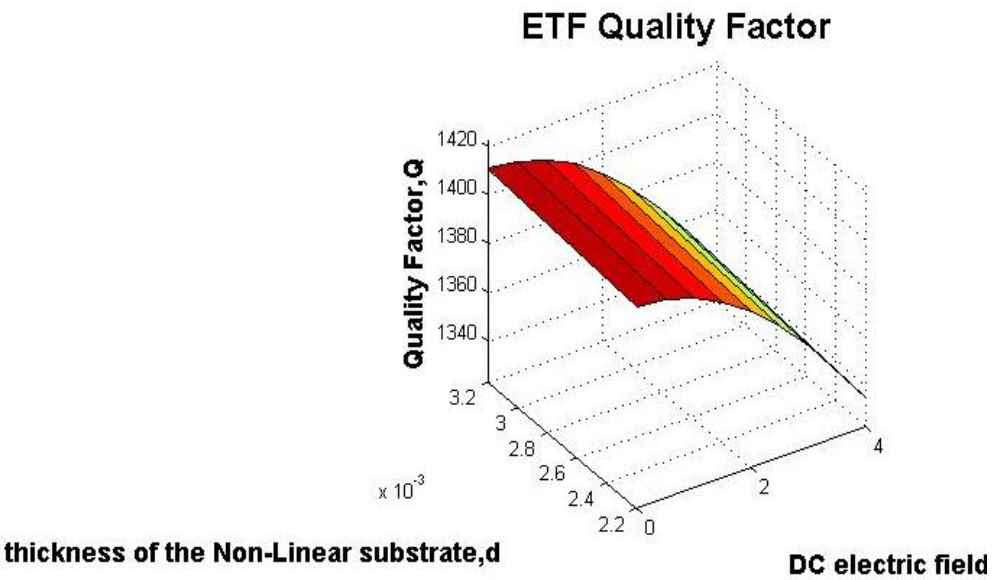

Fig 6.31 Changing DC electric field E (V/cm) and thickness of the substrate line (d), dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO/NGO, at constant thickness of line t1=0.5µm, T=78K.

E KV/cm	**0**	2	4
d µm	**3.2**	2.6	2.2
Q	**1411**	1390	1326
d µm	**2.2**	1.4	
Q	**1397**	1378	

Table 6-9 Changing DC electric field E (V/cm) and thickness of the substrate line (d), dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO/NGO,at constant thickness of line t1=0.5µm, T=78K.

In case of ETF at fig 6-29 and Table 6-5, Q_E value increases with decreasing the dc electric field and increasing the substrate thickness. The maximum result of Q_E ≈1411 at t1=0.5μm and d=2.2cm, but when increase value of d=3.2cm and E=0KV/cm the increase value of Q_E equal 1411. AT E=4 KV/cm, d=2.2cm the decrease value of Q_E equal1326.

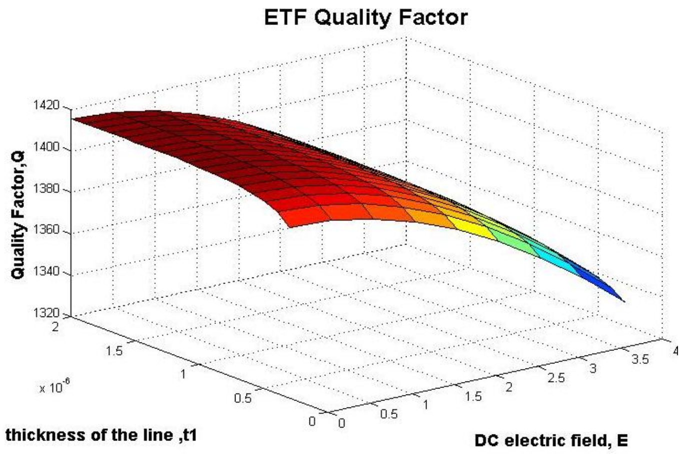

Fig 6.32 Changing thickness of line t1 and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO /NGO at thickness of substrate line d=2.2cm at T=78K.

E	**0**	2	4
t1 **μm**	**0.5**	0.9	0.6
Q	**1406**	1394	1337
t1 **μm**	**1.1**	0.5	0.3
Q	**1413**	1387	1325

Table 6-10 Changing thickness of line t1 and the dc electric field dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO /NGO at thickness of substrate line d=2.2cm at T=78K.

In case of ETF, Q_E value increases with decreasing the dc electric field and increasing the line. The value of Q_E ≈1406 at t1=0.5μm and E=0, but when increase value of t1=0.5μm and E=4KV/cm the increase value of Q_E equal 1337. AT E=0KV/cm, d=2.2cm the decrease value of Q_E equal1326 the maximum result of Q_E ≈.1413 at increase value of t1=1.1 μm

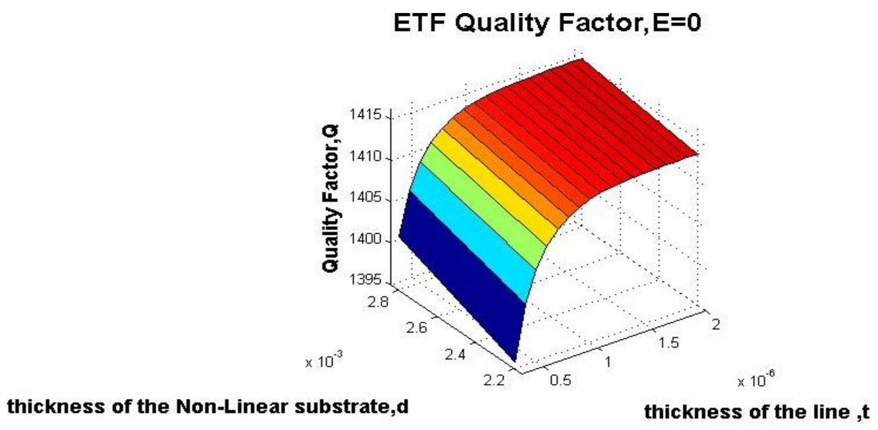

Fig 6-33 Changing thickness of the substrate d with the thickness of line t1 dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO/NGO at constant E=0KV/cm,T=78K.

Q	**1406**	1408	1415	1416
d cm	**2.2**	1.4	2.6	3.2
t1 μm	**0.5**	0.2	0.2	1

Table 6-11 Changing thickness of the substrate d with the thickness of line t1 dependence of quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO/NGO at constant E=0KV/cm, T=78K.

In case of ETF, Q_E value increases with increase of substrate line and increasing the line. The value of Q_E ≈1404 at t1=0.5μm, E=0 and d=2.2 cm but the increase value of Q_E equal 1406. At the d=2.6cm (increase) the value of Q_E ≈.1415 at decrease value of t1=0.2 μm.

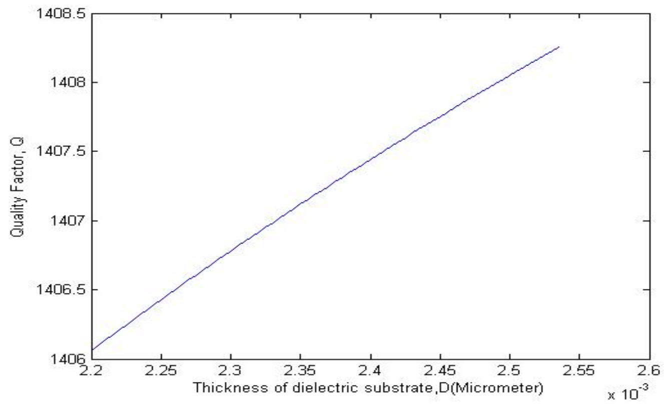

Fig 6-34 Changing thickness of the substrate d with the the quality factor of (ETF), of a YBCO microstrip resonator on a non-linear substrate of STO/NGO at constant E=0KV/cm, T=78K.

d (µm)	2200	2300	2450
QE	1406	1407	1408

Table 6-12 Changing thickness of the substrate d with quality factor of (ETF) at thickness of the line t1=0.5 µm, of an YBCO microstrip resonator on a non-linear substrate of STO at constant E=0KV/cm, T=78K.

In case of ETF, Q_E value increases with increase of substrate line and increasing the line. The value of Q_E ≈1406 at t1=0.5µm, E=0 and d=2.2 cm but the increase value of Q_E equal 1408. At the d=2.56cm.

6-6-3 Comparison between STO and STO/NGO: [10GHZ-78k]:

In the [STO]:

E	***0***	***10***
ε_r	***1842***	***1707***

Table 6-13 Dependence of relative permittivity of STO on the temperature and dc electric field at 10 GHz in STO

Tunability [n] =1842/1707= 10.8≈11%.

In the [STO/NGO]:

E	0	4
ε_r	***1842***	***1818***

Table 6-14 Dependence of relative permittivity of STO on the temperature and dc electric field at 10 GHz in STO/NGO.

Tunability [n] = 1842/1818 =10.13≈10%.

Tunability STO near equal tunability (STO/NGO) since the tunability STO at temperature 78 K and frequency 10 GHz equal 11% , tunability (STO/NGO) at temperature 78 K and frequency 10 GHz equal equal 10 %.

6-6-4 Comparison between Changing the Quality factor (Q) with Frequency (*f*) In STO and STO/ NGO: [78◦K]:

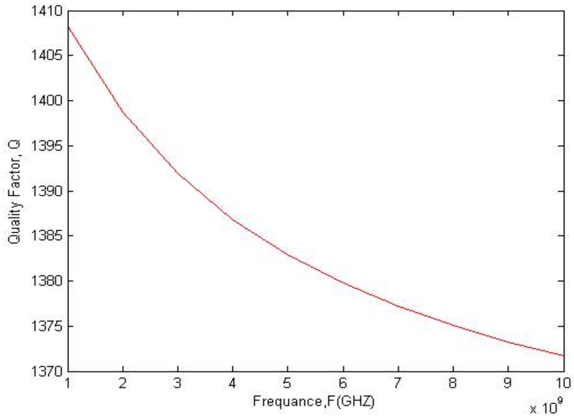

Fig 6-35 Comparison between Changing the Quality factor (Q) with Frequency (f) In STO.

F(Hz)	10^6	10^7	10^8	10^9	**10^10**

Q	1423	1422	1421	1418	**1372**

Table6-15 Comparison between Changing the Quality factor (Q) with Frequency (f) In STO**.**

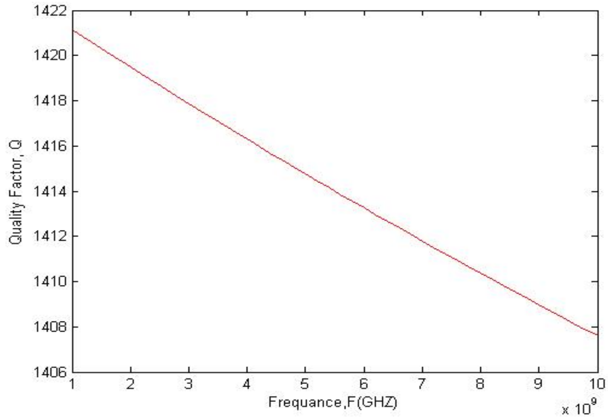

Fig 6-36 Comparison between Changing the Quality factor (Q) with Frequency (f) In STO/NGO.

F(Hz)	10^6	10^7	10^8	10^9	**10^10**
Q	1423	1423	1423	1421	**1406**

Table6-16 Comparison between Changing the Quality factor (Q) with Frequency (f) In STO/NGO.

From Fig 6-35 and Fig 6-36 In case of STO, Q_E value increases with decrease of the frequency. The value of Q_E ≈1372 at t1=0.5µm, E=0, d=2.2 cm and f=10GHz but the increase value of Q_E equal 1423 at f=1MHz. But In case of STO/NGO, Q_E value increases with decrease of the frequency. The value of Q_E ≈1406 at t1=0.5µm, E=0, d=2.2 cm and f=10GHz but the increase value of Q_E equal 1423 at f=1MHz.