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Mutual Coupling Reduction In Microstrip Antenna Array Using Ebg

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Abstract :-

Microstrip antenna array can be used for various application at X and KU-bands . In this paper the design of a microstrip antenna array configurations was 1x2 at 9.46 GHz were presented. A mutual coupling reduction method between closely spaced antenna array elements is proposed by using Electromagnetic Band Gap with T-Shaped slot (EBGT) and with T and L slots (EBGTL) . The simulated results shows that the good performance of antenna array by using EBG structure comparison with the antenna array without the decoupling structures. The mutual coupling in antenna array reducing to -56.83 dB by with EBGT and to -69.26 dB with EBGTL , and the average gain is 9.05 dB , and 9.65 dB with EBGT and EBGTL respectively.

Key word :- EBGTL , gain , mutual coupling, , antenna array, HFSS .

1- INTRODUCTION

Microstrip antenna arrays are well known for being low cost, low profile, easy to design and fabricate. Their easy integration with RF circuit has made them as a good candidate for wireless communication. Thus, in the recent years a lot of research have been done to reach a compact and miniaturized microstrip antenna .The microstrip patch antenna just can provide a medium range for the radiation gain, so they are used in antenna array to achieve a high gain antenna [1].

Surface waves and near fields can lead to coupling between coplanar and patch antennas. Near field coupling arises when an antenna is placed in the near-field zone of other antenna. This coupling is strong in situations where the antennas are placed on dielectric substrates having low permittivity [2].

In such cases, the coupling can result in degradation to the antenna's radiation characteristics. Apparently surface waves are weakly excited in very thin grounded dielectric substrates, space waves dominate as well as produces strong coupling when antennas are close to each other's.

To study of the mutual coupling problem, several research efforts have been devoted to combat the mutual coupling between coupled antennas to improve antenna radiation characteristics [3-4].

Recently some of the methods were used for the reduction of mutual coupling by using some structures like Electrom-agnetic Band Gap (EBG) structure, which can be used to bloke the surface wave [5–8].
Defective ground structure (DGS) disturb the current distribution of antenna's ground plane. Thus, by contr-olling the shape of DGS, the propagation of electromagnetic waves in the substrate layer is controlled and the mutual coupling can be reduced [9]. A slot was designed on the ground plane to decrease mutual coupling between radiating elements [10] . Some other techniques were reported by using slotted complem-entary split ring resonator (SCSRR) [11] and slot combined complementary split ring resonator (SCCSSR) [12] structure to reduce the mutual coupling between the radiating elements.
In this work, rectangular microstrip patch antenna, have been design, with 2- shaped slot [13], liner array of two antennas have been used. Electrom-agnetic Band Gap with T-shaped slot (EBGT), and Electromagnetic Band Gap with L-shaped slot loaded to T-shaped slot (EBGTL) between two elements of array to reducing the mutual coupling..

2. *Design of microstrip antenna array*

The antenna array of (1x2) is simulated by arranging these two microstrip patch antennas in linear configuration . Each patch element is excited individually using separate port and the responses integrated, overall radiation pattern of the two elements linear array antennas is simulated using HFSS software.

The dimension of 1x2 array shown in figure (1). The substrate chosen for the proposed antenna is FR4-epoxy with dielectric constant of 4.4 and a thickness of 1.66 mm.The distance between two patches (edge to edge) is d .

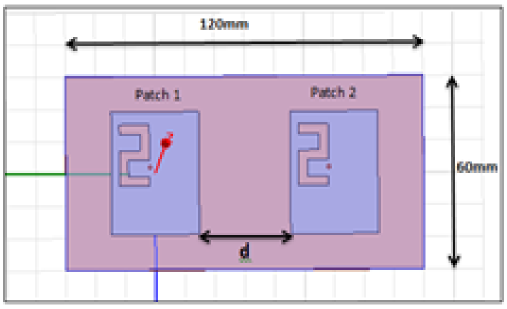


Figure (1):1x2 array dimension of antenna

3. EBG structure

3.1 : EBG with T-shaped slot (EBGT)

Basically electromagnetic band gap (EBG) structures are realized by periodic arrangement of dielectric materials and shows characteristics of band-pass or band stop and makes isolation between components [14-15]. Mutual Coupling between the microstrip antenna arrays is the essential problem that always exists.

To solve this problem, metamaterial is used in a rectangular patch antenna array substrate in order to reduce mutual coupling between array antennas [16]. To study this effect, we use the simplest form of EBG patterns represented generically by the schematic shown in figure (2). These structures are charact-erized by periodic metallic patches connected to a common ground (or reference) plane by via. In this work we consider rectangular EBG patches with parameters as shown in previous figure, where the length and the width is L_E , W_E respectively.

T-shaped slot was made in the EBG cells, the dimensions of the EBG unit cell as shown in the figure (2).

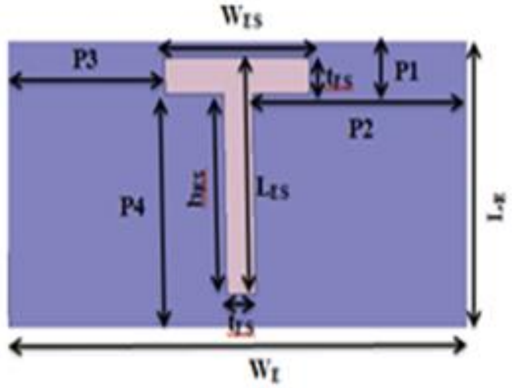
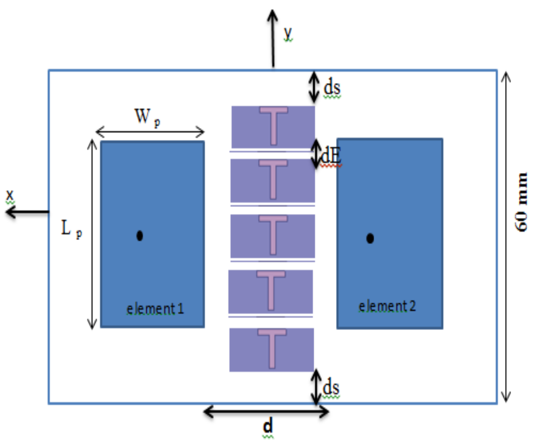


Figure (2): dimensions of T shaped slot

EBGT cells placed in the distance between adjacent elements in the array, as in figure (3) , the distance separation between the EBG cells is dE and the distance from the upper edge of the ground to the upper edge of the first EBG cell (and the distance from the lower edge of the ground to the lower edge of the last EBG cell) is ds .

Figure (3): antenna array with EBGT Structure.



3.2: EBGT with dual L-shape slot (EBGTL)

Dual L – shaped loading to T-shaped slot was made in the EBG cell, the dimensions if the EBGTL cell as shown in the figure (4).

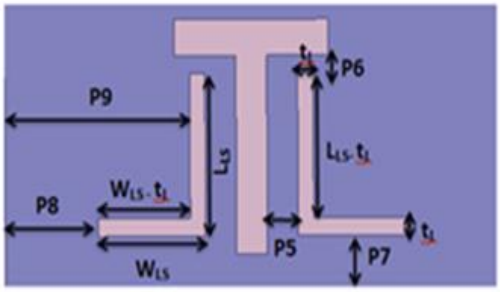


Figure (4): dimensions of L and opposite L shaped slot

EBGTL cells are placed the distance between adjacent elements of the array. As mentioned above were shown in the figure (5) .

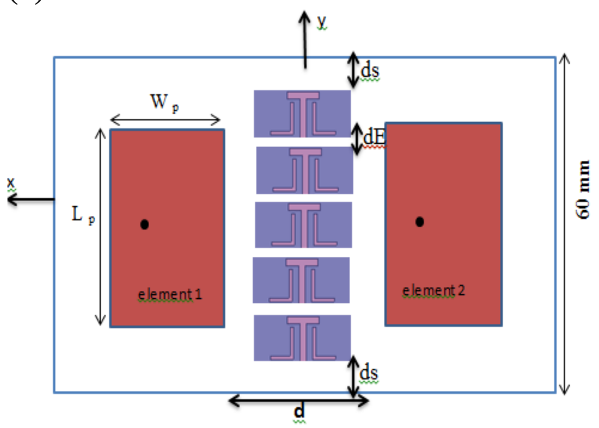


Figure (5): antenna array with EBGTL Structure.

4. SIMULATION RESULTS

The design and simulation of 1x2 antenna array of two elements were done with aid of HFSS software is shown in figure (6).

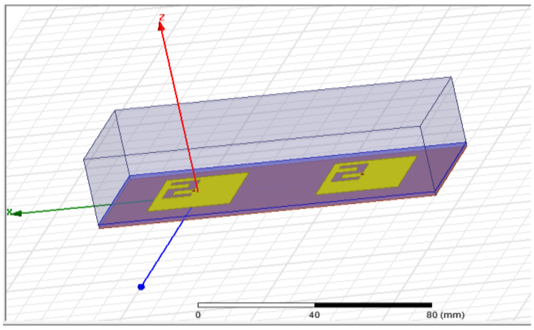


Figure (6) :linear antenna array of two elements

Some of antenna parameters, such as the band width , VSWR, radiation pattern and the gain, for 1×2 antenna array are demonstrated in the next figures. S parameter has been performed for microstrip 1×2 patch array antenna with coaxial feed . The center frequency is selected as the one at which the return loss is minimum. Figure (7) shows that the return loss for 1x2 patch antenna array for different d .

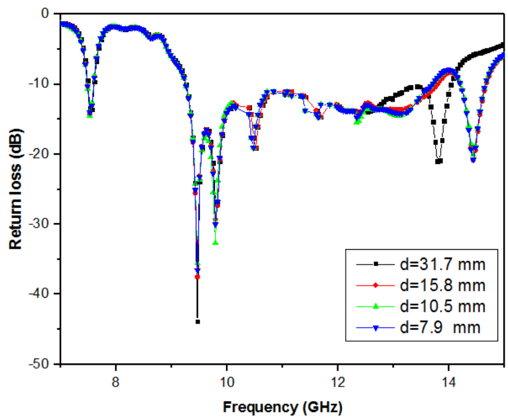


Figure (7) : Return losses of linear antenna arrays a function of spacing between elements

The resonance frequency of the antenna is 9.46 GHz . In figure (7) observe that, for λ , λ/2 , λ/3 and λ/4 separation there is no significance differences in the resonance frequency, while the values of return losses are affected as shown in table (1).

Table (1) Return losses of antenna array for different separation

d (mm)	S_{11} (dB)
λ	-43.85
λ/2	-37.35
λ/3	-35.86
λ/4	-36.42

Figure (8) shows that, there is no change in VSWR for λ , λ/2 ,λ/3 and λ/4 separation between the elements . The value of vswr is 1.0129 at frequency 9.46 GHz .

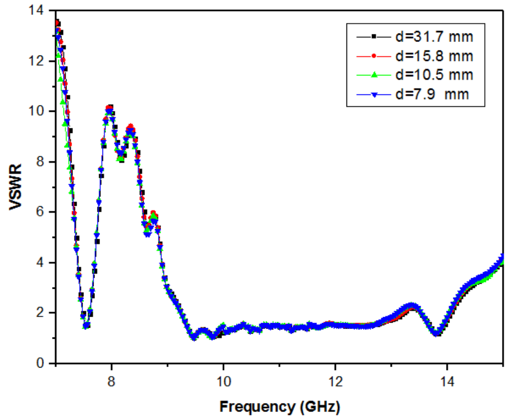
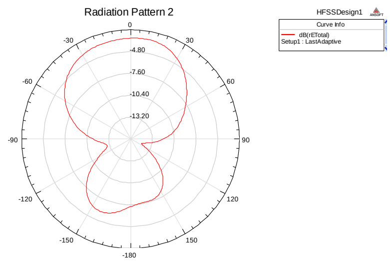


Figure (8): VSWR of antenna array for different separation

The 2-D radiation pattern of antenna array with d= λ shown in figure (9) .



Figure(9a): E-Plane of the antenna array

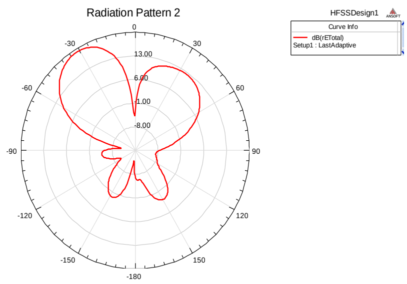


Figure (9b): H -Plane of the antenna array

The gain vis frequency plot is shown in figure (10). It shows that the gain is 9.55 dB at 9.46 GHz, and the average gain is 7.98dB.

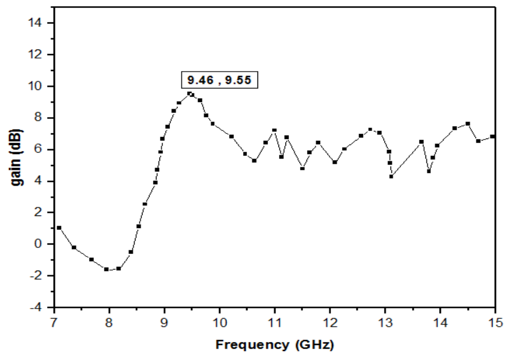


Figure (10): Gain of the antenna array with d=λ

As mention above the performance parameter of a 1×2 microstrip antenna array with d=λ is shown in table (2).

Table (2) Microstrip antenna array parameters.

Frequency	9.46 GHz
S_{11}	-43.856 dB
Bandwidth	4.8 GHz (51%)
VSWR	1.0129
average gain	7.98 dB

5. Result of Mutual Coupling of Antenna Arrays

The parametric simulation results of mutual coupling for the antenna array are demonstrated in figure (11).

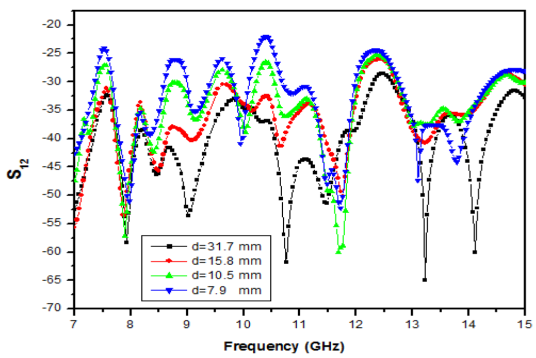


Figure (11): Mutual coupling of antenna array for different separation

In figure (11) shown us clearly observed that as the separation between two antenna is decreased the mutual coupling is increased. The value of mutual coupling for different separation shown in table (3) .

Table (3) mutual coupling of 1x2 array for different separation

d (mm)	S_{12} (dB)
λ	-36.36
λ/2	-33.00
λ/3	-30.03
λ/4	-27.65

6. Reduction Mutual Coupling in antenna array by using EBG

6.1. Simulation of antenna array with EBGT.

When we used the EBG patches with T-shaped slot at the distance between adjacent elements of the array, as shown in the figure (12) and parametric study with different dimensions of the EBG cell as in figure (2) where show different values of mutual coupling and band width as in tables (4-7).

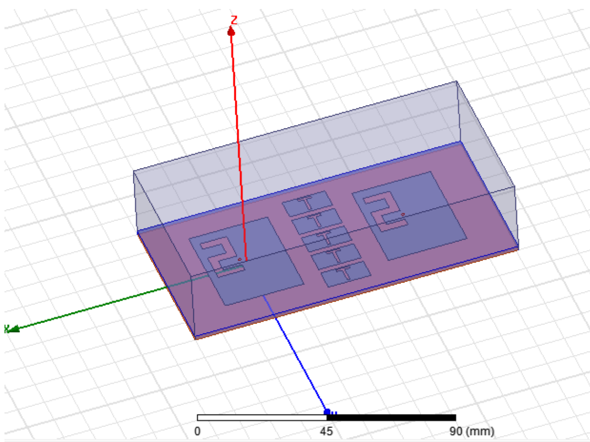


Figure (12) : The antenna array with EBGT

Table (4) : mutual coupling and band width for Different dimension of EBGT

L_E (mm)	W_E (mm)	S_{12} (dB)	B.W (GHz)
7	16	-42.93	4.72
8		-56.53	4.99
8.2		-50.10	4.84
8.4		-50.93	4.74
8.6		-52.05	4.76
8.8		-53.3	4.93
9		-51.00	4.76
8	15	-46.6 4	4.76
	16	-56.53	4.99
	16.2	-54.24	4.96
	16.4	-53.41	4.85
	16.6	50.87	4.76
	16. 8	-51.97	4.76
	17	-52.92	4.76

Table (5) : mutual coupling and band width for Different dimension of T-shaped slot

W_{ES} (mm)	t_{ES} (mm)	S_{12} (dB)	B.W (GHz)
4	1	-51.50	4.82
5		-56.53	4.99
5.2		-53.01	4.92
5.4		-52.23	4.88
5.6		-50.29	4.86
5.8		-51.09	4.82
6		-49.99	4.86
5	0.5	-50.81	4.84
	1	-56.53	4.99
	1.2	-52.22	4.96
	1.4	-51.90	4.86
	1.6	-51.01	4.86
	1. 8	-50.48	4.86

Table (6) : mutual coupling and band width for Different h_{ES} with t_{ES} of T-shaped slot

h_{ES} (mm)	t_{ES} (mm)	S_{12} (dB)	B.W (GHz)
4	1	-52.30	4.86
5		-52.00	4.80
5.25		-53.45	4.91
5.5		-56.53	4.99
5.75		-52.34	4.90
6		-51.26	4.86
6.25		-51.02	4.82
5.5	0.5	-50.81	4.84
	1	-56.53	4.99
	1.2	-52.22	4.96
	1.4	-51.90	4.86
	1.6	-51.01	4.86
	1. 8	-50.48	4.86

Table (7) : mutual coupling and band width for different dE and ds of antenna array with EBG T

dE (mm)	ds(mm)	S_{12} (dB)	B.W (GHz)
0	10	-49.42	4.88
1	8	-56.83	5.02
2	6	-56.53	4.99
3	4	-47.90	4.86

From tables (4-7), the best values were selected for the dimensions of the EBG cell and the dimensions of the T-shaped slot, list in the table (8) .

Table (8): optimum dimension for EBGT

symbol	Value(mm)
L_E	8
W_E	16
d	31.7
L_{ES}	6.5
W_{ES}	5
t_{ES}	1
h_{ES}	5.5
dE	1
ds	8
P1	1.5
P2	7.5
P3	5.5
P4	6.5

The simulation results of 1x2 antenna array with EBG of dimensions in table (8), such as return loss , mutual coupling, radiation pattern and gain and comparative with results without EBG patches, as shown in figures. (13) to (15).

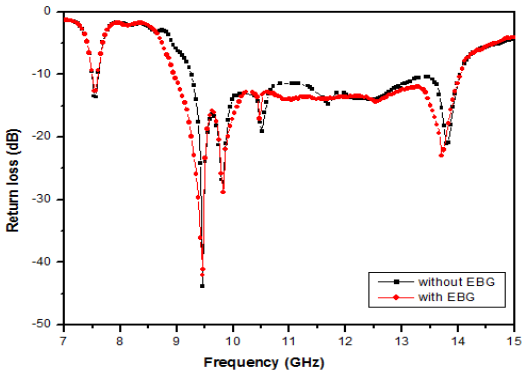


Figure (13): Return loss of the array with and without EBGT

The return loss of linear array for proposed antenna with EBG of T-shaped slot compared with the return loss of the linear array without EBG is shown in figure (13). The figure show increasing in the band width when using EBG with T-shaped slot, as shown in table (9).

The mutual coupling between proposed antenna in array with EBG of T-shaped slot in comparison with the mutual coupling of the linear array of the same antenna without EBG is shown in figure (14). The figure shows that, the reducing in mutual coupling when used EBG with T-shaped slot, as shown in table (9).

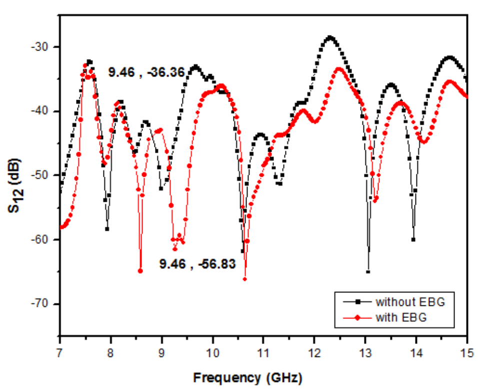


Figure (14): Mutual coupling of 1x2 array with and without EBGT

The 2-D radiation pattern (E-plane and H-plane) of proposed antenna in array with EBG patches of T-shaped slot shows in figure (15) .

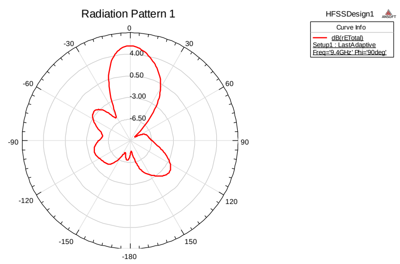


Fig (15a): E-plane pattern of the array with EBGT

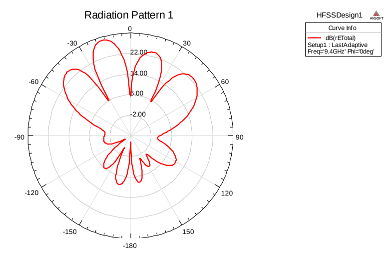


Figure (15b): H-plane pattern of the array with EBGT

The gain of array for proposed antenna with and without EBGT is shown in figure (16). The figure show increasing in the gain when using EBGT, where the maximum gain is 10.95dB at 9.46 GHz and the average of the gain is 9.05 dB , this shown in table (9).

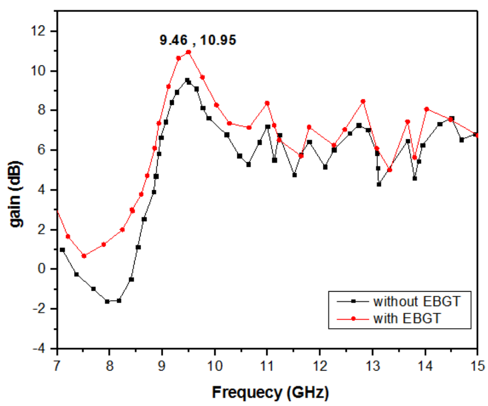


Figure (16): gain of array with and without EBGT

As shown above the performance parameter of a 1×2 microstrip array antenna with and without EBG of T-shaped slot at dimension of table (8) is shown in Table (9)

Table (9) parameters of 1×2 Patch Antenna array with and without EBGT

Parameters	Without EBGT	With EBGT
S_{12}	-36.36 dB	-56.83 dB
Bandwidth	4.8 GHz	5.02 GHz
VSWR	1.0129	1.0178
average gain	7.98 dB	9.05dB

6.3. Simulation of the antenna array with EBGTL cells.

When used the EBG cells with L-shaped slot loading T- shaped slot at the distance between adjacent elements of the antenna array, as shown in figure (17) and parametric study with the aid of HFSS done for the different dimensions of the EBG cell with slots as in figure (4). different values of mutual coupling and band width were obtained as in tables (10) to (14) .

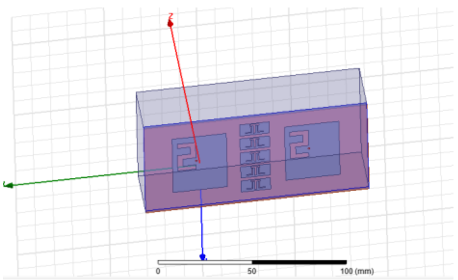


Figure (17) : 1x2 antenna array with EBGTL

Table (10) : mutual coupling and band width for Different dimension of EBGTL

L_E (mm)	W_E (mm)	S_{12} (dB)	B.W (GHz)
7		-35.76	4.76
8		-62.27	5.23
8.2		-54.32	4.92
8.4	16	-51.77	4.84
8.6		-52.15	4.86
8.8		-52.59	4.86
9		-51.68	4.86
	15	-49.53	4.74
	16	-62.27	5.23
	16.2	-55.32	5.01
8	16.4	-54.40	4.98
	16.6	-53.10	4.87
	16. 8	-52.70	4.82
	17	-51.20	4.76

Table (11) : mutual coupling and band width for Different dimension of L-slot loaded T- slot of EBG

W_{ES} (mm)	t_{ES} (mm)	S_{12} (dB)	B.W (GHz)
4		-52.32	4.86
5		-62.27	5.23
5.2		-54.37	5.01
5.4	1	-53.29	4.96
5.6		-52.03	4.87
5.8		-51.59	4.86
6		-60.19	4.98
	0.5	-52.00	4.85
	1	-62.27	5.23
5	1.2	-56.43	5.10
	1.4	-55.94	5.02
	1.6	-53.21	4.93
	1. 8	-52.30	4.89

Table (12) : mutual coupling and band width for Different h_{ES} with t_{ES} of L-slot loaded T-shaped slot of EBG

h_{ES} (mm)	t_{ES} (mm)	S_{12} (dB)	B.W (GHz)
4		-51.75	4.84
5		-50.46	4.83
5.25		-55.93	4.95
5.5	1	-62.27	5.23
5.75		-58.32	5.10
6		-56.01	4.98
6.25		-55.20	4.93
	0.5	-52.00	4.85
	1	-62.27	5.23
	1.2	-56.43	5.10
5.5	1.4	-55.94	5.02
	1.6	-53.21	4.93
	1. 8	-52.30	4.89

Table (13) : mutual coupling and band width for Different t_L with W_{LS} and L_{LS} of L-slot loaded T-shaped slot of EBG

t_L (mm)	W_{LS} (mm)	L_{LS} (mm)	S_{12} (dB)	B.W (GHz)
0.25	2.75	4.25	-52.26	4.86
0.50	3.00	4.5	-62.27	5.23
0.75	3.25	4.75	-57.93	5.15
1.00	3.5	5	-55.57	4.97
1.25	3.75	5.25	-56.32	4.99
1.50	4	5.5	-57.10	5.01

Table (14) mutual coupling and band width for different d_E and d_S of antenna array with EBGTL

dE (mm)	ds (mm)	S_{12} (dB)	B.W (GHz)
0	10	-46.80	4.80
1	8	-69.26	5.28
2	6	-62.27	5.23
3	4	-54.75	4.88

From the tables (10-14) above, the best values were selected for the dimensions of the EBG patches with L-slot loaded T-slot, shown in table (15) .

Table (15): optimum dimension for EBGTL

Symbole	Value (mm)
L_E	8.0
W_E	16.0
d	31.7
L_{ES}	6.5
W_{ES}	5.0
t_{ES}	1.0
h_{ES}	5.5
dE	1.0
ds	8.0
t_L	0.5
L_{LS}	4.5
W_{LS}	3.0
P1	1.5
P2	7.5
P3	5.5
P4	6.5
P5	1.0
P6	0.5
P7	1.5
P8	3.0
P9	6.0

The simulation results of 1x2 antenna array with EBG of opposite L- shaped slot loaded T-shaped slot of dimensions in table (15) , such as return loss , mutual coupling , radiation pattern and gain and compared with results of without EBG , are shown in figures (18) to (21) .

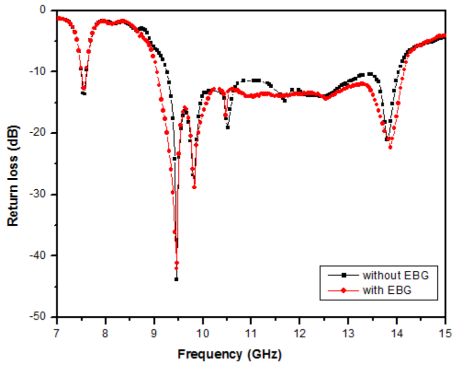


Figure (18): Return loss of array with and without EBGTL

The return loss of linear array of proposed antenna with EBGT compared with the return loss of same array without EBGTL is shown in figure (18). This figure shows more increasing in the band width when using EBG with opposite L-shaped slot loaded T-shaped slot, as shown in table (16).

The mutual coupling between the elements in array with EBGTL comparison with the mutual coupling of the same array of proposed antenna without EBGTL is shown in figure (19). The figure shows a reducing mutual coupling by 33dB when used EBGTL , as shown in table (16) .

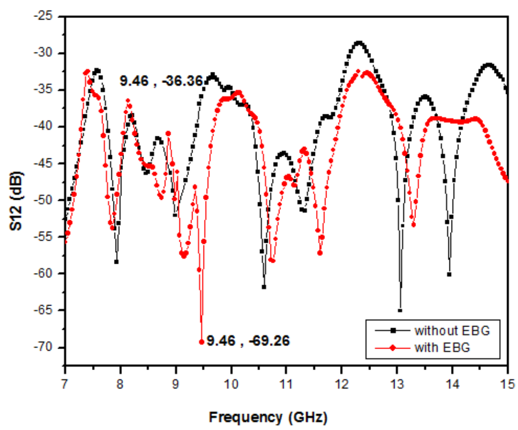


Figure (19): Mutual coupling of the array with and without EBGTL cell

The 2-D radiation pattern (E-plane and H-plane) of proposed antenna in array with EBGTL ,show in figure (20) .

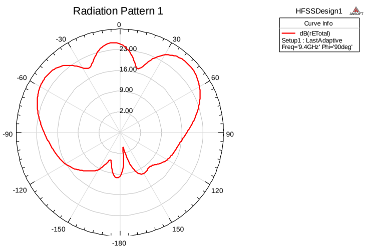


Figure (20a): E-plane pattern of array with EBGTL

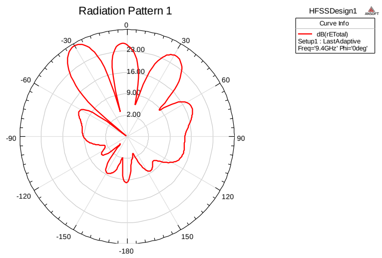


Figure (20b): H-plane pattern of array with EBGTL

The gain of array of proposed antenna with and without EBGTL is shown in figure (21). The figure shows more increasing in the gain when using EBGTL , where the maximum gain is 11.65 dB at 9.46 GHz and the average gain is 9.69 dB as shown in table (16).

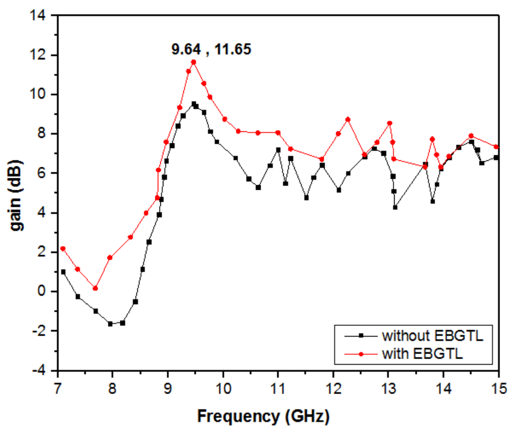


Figure (21): gain of array with and without EBGTL

As shown above the performance parameter of a 1×2 microstrip antenna array with and without EBGTL at dimension of table (15) is shown in Table (16).

Table (16) parameters of 1×2 Patch Antenna array with and without EBGTL

parameters	Without EBGTL	With EBGTL
S_{12}	-36.36 dB	-69.26 dB
Bandwidth	4.8 GHz	5.28 GHz
VSWR	1.0129	1.061
average gain	7.98 dB	9.69 dB

6.CONCLUSION

According to the previous compreh-ensive studies in selecting the optimum dimensions for the EBG cells in order to enhancing the performance of the array antenna, also reduction the mutual coupling between the elements .It shows that as used the EBGT ,and EBGTL between patch elements of the antenna array , reducing the mutual coupling , and increases in the band width and gain of the antenna array , The return loss and VSWR give different values at 9.46 GHz . The improved bandwidth is useful for high frequency of X and KU bands radar application. Future work will include more elements array configu-rations like 2x2 microstrip antenna arrays for higher gain and broad bandwidth operated at X and KU bands.

Table (21) : Comparative summary of all configurations

parameters	Without EBG	With EBGT	With EBGTL
S_{12}	-36.36 dB	-56.83 dB	-69.26 dB
Bandwidth	4.8 GHz	5.02 GHz	5.28 GHz
VSWR	1.0129	1.0178	1.061
average gain	7.98 dB	9.05 dB	9.69 dB

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