

MICROSTRIP ARRAY ANTENNA

SALINA BT UTON



Universiti Malaysia Sarawak
1999

TK
7871.6
S165
1999

BORANG PENYERAHAN TESIS

Judul: MICROSTRIP ARRAY ANTENNASESI PENGAJIAN: 1998 / 99Saya SALINA BT UTON

(HURUF BESAR)

mengaku membenarkan tesis ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

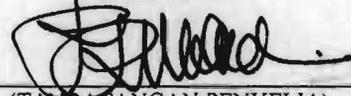
1. Hakmilik kertas projek adalah di bawah nama penulis melainkan penulisan sebagai projek bersama dan dibiayai oleh UNIMAS, hakmiliknya adalah kepunyaan UNIMAS.
2. Naskhah salinan di dalam bentuk kertas atau mikro hanya boleh dibuat dengan kebenaran bertulis daripada penulis.
3. Pusat Khidmat Maklumat Akademik, UNIMAS dibenarkan membuat salinan untuk pengajian mereka.
4. Kertas projek hanya boleh diterbitkan dengan kebenaran penulis. Bayaran royalti adalah mengikut kadar yang dipersetujui kelak.
5. * Saya membenarkan/~~tidak membenarkan~~ Perpustakaan membuat salinan kertas projek ini sebagai bahan pertukaran di antara institusi pengajian tinggi.
6. ** Sila tandakan (✓)

- SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).
- TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan).
- TIDAK TERHAD



(TANDATANGAN PENULIS)

Disahkan oleh



(TANDATANGAN PENYELIA)

Alamat tetap: NO. 7, KPG SEMARANG,PETRA JAYA, 93050 KUCHING, SARAWAK.DR MOHAMAD KADIM SUADI

Nama Penyelia

Tarikh: 25 Feb 1999Tarikh: 25/2/99

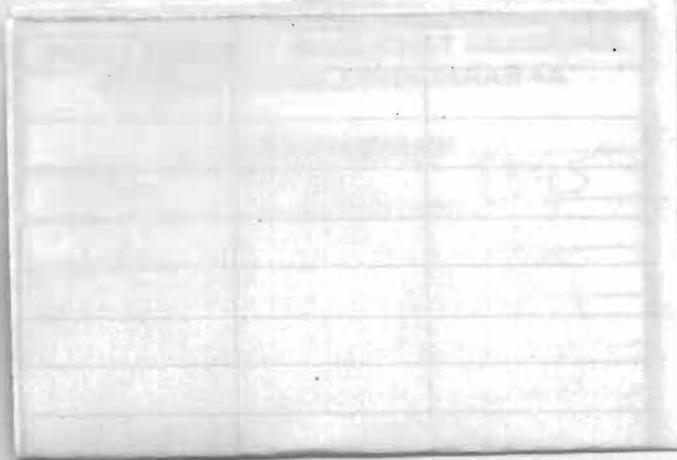
- CATATAN * Potong yang tidak berkenaan.
- ** Jika Kertas Projek ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/ organisasi berkenaan dengan menyertakan sekali tempoh kertas projek. Ini perlu dikelaskan sebagai SULIT atau TERHAD.



0000078225

MICROSTRIP ARRAY ANTENNA

SALINA BT UTON



Dikemukakan kepada
Fakulti Kejuruteraan, Universiti Malaysia Sarawak
Sebagai Memenuhi Sebahagian Daripada Syarat
Penganugerahan Sarjana Muda Kejuruteraan
Dengan Kepujian (Kejuruteraan Elektronik dan Telekomunikasi)
Februari 1999

Acknowledgement

Alhamdulillah, I would like to express my sincere thanks to the following people: to my supervisor, Mr. Suadi for supervising this project. Not forgetting to thank Mr. Suadi for helping me with the equipment needed and also to those who have helped directly or indirectly in preparing this project.

Untuk Ayahanda Uton b Bujang dan Ibuanda Hj. Morshidi, serta

Bonda Narimah bt Hj. Morshidi

sekeluarga

Acknowledgement

Bismillahirrahmanirrahim. I would like to express my sincere thanks to Dr. Mohamad Kadim b. Suaidi for supervising this project. Not forgetting to Encik Wan Abu Bakar for helping me with the equipment needed and also to those who are involved directly or indirectly in preparing this project.

Lastly, my special thanks goes to my family especially my parents for their encouragement and support.

Abstrak

Teknik dalam rekaan antena Jaluran Kecil diketengahkan dengan menekankan beberapa pertimbangan yang perlu diambil kira oleh pereka. Antena Jaluran Kecil sering digemari kerana strukturnya yang nipis, proses penghasilan yang mudah, kesesuaiannya terhadap MICs (Litar Bersepadu Gelombang Mikro) serta struktur geometrinya yang ringkas. Pengenalan dan ulasan mengenai antena Jaluran Kecil dibincangkan di dalam Bab 1,2 dan 3. Penekanan terhadap teknik secara teori dan praktikal turut diketengahkan. Pertimbangan yang perlu diambil kira dalam proses reka antena Jaluran Kecil dibincangkan di dalam Bab 5, manakala proses bagaimana antena direka pula dibincangkan di dalam Bab 6. Aplikasi antena ini di dalam sistem komunikasi pula dibincangkan di dalam Bab 7.

microstrip antenna communication system are discussed in Chapter 7.

DEDICATION	ii
------------	----

Abstract

ACKNOWLEDGEMENT	iii
-----------------	-----

ABSTRACT	iv
----------	----

Microstrip antenna array techniques are reviewed with attention to the basic considerations important to user or the designer. Microstrip arrays are often chosen because of their ruggedness, ease of manufacturing by printed circuit techniques, compatibility with MMICs, and thin, conformal geometry. The introduction and the literature review on microstrip array antenna are discussed in Chapter 1, 2 and 3. A survey of microstrip antenna elements is presented, with emphasis on theoretical as well as practical design techniques. Chapter 4 emphasis on the practical tools in designing microstrip antenna. The design consideration in microstrip antenna is presented in Chapter 5 while the design process of microstrip antenna covered with a dielectric layer is presented in Chapter 6. The applications of microstrip antenna communication system are discussed in Chapter 7.

CHAPTER 1	
-----------	--

LITERATURE REVIEW	5
-------------------	---

2.1	5
-----	---

2.2	9
-----	---

2.3	10
-----	----

2.4	10
-----	----

2.5	10
-----	----

DEDICATION	ii
ACKNOWLEDGEMENT	iii
ABSTRAK	iv
ABSTRACT	v
CHAPTER 1	
PROJECT OVERVIEW	1
CHAPTER 2	
INTRODUCTION	3
2.1 History	3
2.2 What is microstrip transmission line?	4
2.3 Microstrip Line Realization	6
CHAPTER 3	
LITERITURE REVIEW	9
3.1 Array definition	9
3.2 Element and Array Pattern	9
3.3 Pattern Multiplication	10
3.4 Calculation of array pattern	10
3.5 Impedance matching	10
3.6 Ground	30
3.7 Other possibilities	31

CHAPTER 4

PRACTICAL TOOLS FOR MICROSTRIP DESIGN

4.1	Techniques of artwork	12
4.1.1	Coordinatograph.	12
4.1.2	Photoplotter.	13
4.1.3	Pattern generator.	13
4.2	Substrates.	14
4.3	Coating and etching	15
4.4	Process of etching	17
4.5	Microstrip components	20
4.5.1	Capacitors	20
4.5.2	Lumped components	20

CHAPTER 5

5.1	Advantages and disadvantages of using microstrip.	61
DESIGN CONSIDERATION IN MICROSTRIP		
5.1	Spacing.	22
5.2	Substrate.	23
5.3	Amplitude and Phase Accuracy	23
5.4	Mutual Coupling	28
5.5	Radiation from the feed network	28
5.6	Cross polarization	29
5.7	Diffraction effect	29
5.8	Ground	30
5.9	Other consideration	31

THE DESIGN PROCESS

Figure 2a	Equivalent circuit of microstrip line circuit	3
6.1	Radiation Pattern	33
Figure 4a		17
6.2	Directivity and Gain	38
Figure 4b		21
6.3	The pattern of array	39
Table 5a		25
6.4	Experiment setup	41
Figure 5a		
6.5	Results	44
Figure 5b		26
6.6	Conclusion	50
Figure 6a		
		37

CHAPTER 7

Figure 5a	Design of rectangular microstrip antenna	32
APPLICATION OF MICROSTRIP ANTENNA IN COMMUNICATION SYSTEM		
Figure 6b		34

Figure 6c		36
Figure 6d		37
7.1	Advantages and disadvantages of using microstrip.	51
Figure 6e		39
7.2	Mobile Satellite Communication	53
Figure 6f		40
7.3	Application for Direct Broadcast Satellite (DBS) System	54
Figure 6g		41
7.4	NonSatellite-Based Application	55
Table 6a		43

CHAPTER 8

CONCLUSION AND RECOMMENDATION		58
--------------------------------------	--	-----------

Figure 6j		44
Figure 6k		45
Figure 6l		46
Figure 6m		47

LIST OF FIGURES	Page	
Figure 2a	Realization of microstrip-line circuit	8
Figure 4a	Process of etching	17
Figure 4b	Examples of lumped inductors	21
Table 5a	Required amplitude and phase tolerance	25
Figure 5a	Calculated pattern for a 40-element plane linear array	26
Figure 5b	Calculated pattern of array with Gaussian distributed	27
Figure 6a	Resonant rectangular microstrip antenna	32
Figure 6b	Equivalent wire antenna	34
Figure 6c	In-phase values of wire currents	36
Figure 6d	Examples of radiation pattern	37
Figure 6e	Spacing between element	39
Figure 6f	The pattern of the designed antenna	40
Figure 6g	Experiment setup for testing the antenna	41
Table 6a	The characteristic of both antenna	43
Figure 6h	Radiation pattern (E-plane)	44
Figure 6i	Radiation pattern (H-plane)	44
Figure 6j	Variation of impedance for different dielectric constant	45
Figure 6k	Radiation pattern for reference antenna, in polar coordinates, α against θ	46
Figure 6l	Radiation pattern for reference antenna, in Cartesian coordinates, α against θ	47

Figure 6m	Radiation pattern for designed antenna, in polar coordinates, a against θ	48
Figure 6n	Radiation pattern for designed antenna, in Cartesian coordinates, a against θ	49
Figure 7a	Microstrip reflectarray surface-mounted on building's wall for DBS application	56
Figure 7b	Mechanically steered microstrip array antenna for mounting on trains for DBS application	56
Figure 7c	S-band microstrip array with briefcase size for DBS radio Service	57
Figure 7d	Flexible microstrip patch mounted on a curved surface for hyperthermia medical application	57

The design of microstrip array antenna is fundamentally the same as the design of other types of arrays. The first consideration that should be taken into account is the frequency operation. It is important to know the frequency of operation since the value of wavelength need to be calculated from the basic formula $\lambda = c/f$ where c is the speed of light, 3×10^8 m/s.

When the frequency of operation of the antenna is known, then the process of designing the arrays can be initiated. There are some consideration that should be taken in order to get the array pattern. For instance the spacing between each element, the dielectric substrate to be used, the length and width of each element, the matching of the impedance

CHAPTER 1

PROJECT OVERVIEW

The purpose of this paper is to analyze the consideration that should be taken in designing microstrip array antenna. Microstrip antenna is preferable than other since it has a low profile, light in weight, can be made conformal and it is well suited to integration with microwave integrated circuit (MIC). The process of etching is also presented in this paper. with the example of etching gold and chromium.

The design of microstrip array antenna is fundamentally the same as the design of other types of arrays. The first consideration that should be taken into account is the frequency operation. It is important to know the frequency of operation since the value of wavelength need to be calculated. from the basic formula $c = f\lambda$ where c is the speed of light , 3×10^8 m/s.

When the frequency of operation of the antenna is known, then the process of designing the arrays can be initiated. There are some consideration that should be taken in order to get the array pattern. For instance the spacing between each element, the dielectric substrate to be used, the length and width of each element, the matching of the impedance

and some other consideration which has been discussed in the later chapters.

CHAPTER 2

There are also some calculations, which are used to specify the characteristic of the arrays including the effective relative dielectric constant of microstrip, the wavelength, characteristic impedance, losses in microstrip lines, etc.

2.1 History

The pattern of the microstrip array that has been designed is also shown with the characteristics of the arrays. While in the last chapter, the applications of microstrip antennas are discussed.

However, other than the original of Deschamps report, work was not reported in the literature until the early 1970's when a conducting strip radiator separated from a ground plane by a dielectric substrate was described by Deros.

In 1975, Coates et al, Howell, Weinchel, and James and Wilson reported work in using microstrip patch elements. Leo et al, who used the modal-expansion technique to analyze rectangular, circular, semicircular and triangular patch shapes, published the first mathematical analysis of a microstrip patch shape in 1977.

By 1978, the microstrip antenna was becoming much more widely known and used as a variety of communication system. In October 1979, the first symposium devoted to microstrip antenna materials, practical design, novel configurations, and theoretical models was held at New Mexico State University (NMSU).

CHAPTER 2

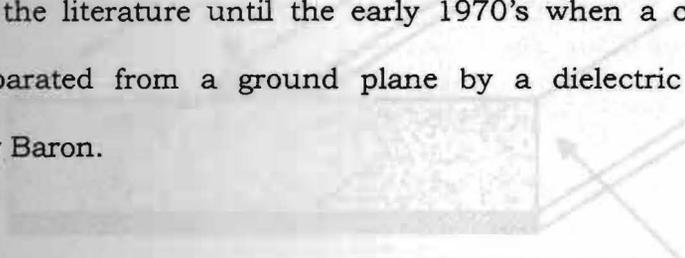
INTRODUCTION

2.1 What is microstrip transmission line?

2.1 History

Microstrip antenna dates back about 26 years to work in the U.S.A by Deschamps and in France by Gutton and Bassinot. Shortly thereafter, Lewin investigated radiation from stripline discontinuities. Additional studies were undertaken in the late 1960's by Kaloi who studied basic rectangular and square configurations.

However, other than the original of Deschamps report, work was not reported in the literature until the early 1970's when a conducting strip radiator separated from a ground plane by a dielectric substrate was described by Baron.

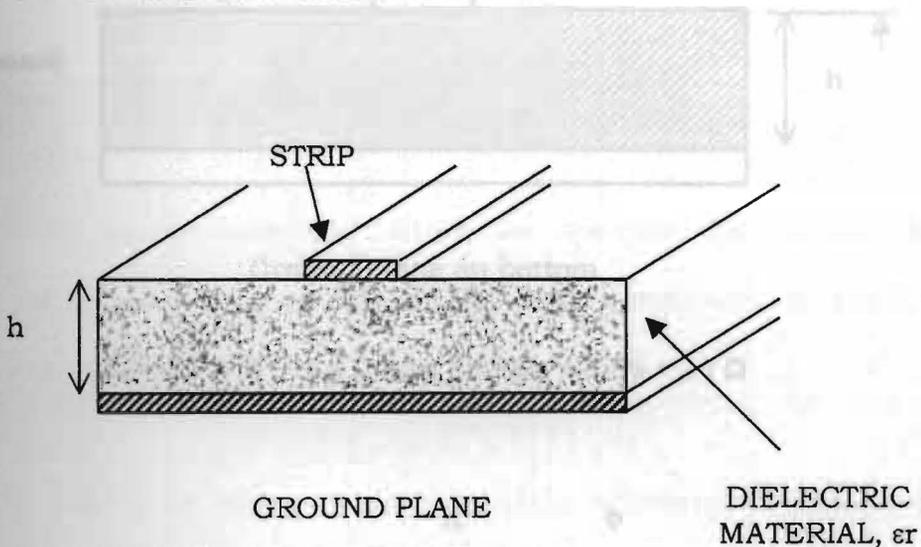


In 1975, Garvin et al, Howell, Weinchel, and Janes and Wilson reported work in basic microstrip patch elements. Leo et al, who used the modal-expansion technique to analyse rectangular, circular, semicircular and triangular patch shapes, published the first mathematical analysis of a wide variety of microstrip patch shapes in 1977. Leo et al used a dielectric material, with the dielectric material being between the strip and an infinite ground plane.

By 1978, the microstrip patch antenna was becoming much more widely known and used in a variety of communication system. In October 1979, the first international meeting devoted to microstrip antenna materials, practical designs, array configurations, and theoretical models was held at New Mexico State University (NMSU)

2.2 What is microstrip transmission line?

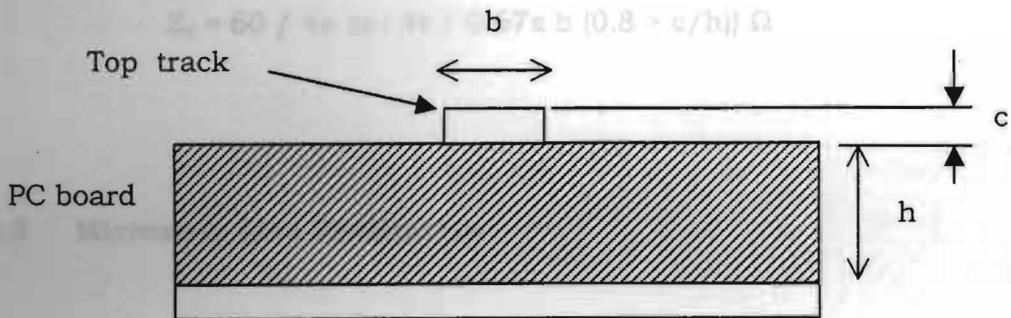
Microstrip transmission line is the kind of "high grade" printed circuit construction, consisting of a track of copper or other conductor on an insulating substrate. There is a "backplane" on the other side of the insulating substrate, formed from similar conductor. Microstrip is therefore a variant of 2-wire transmission line.



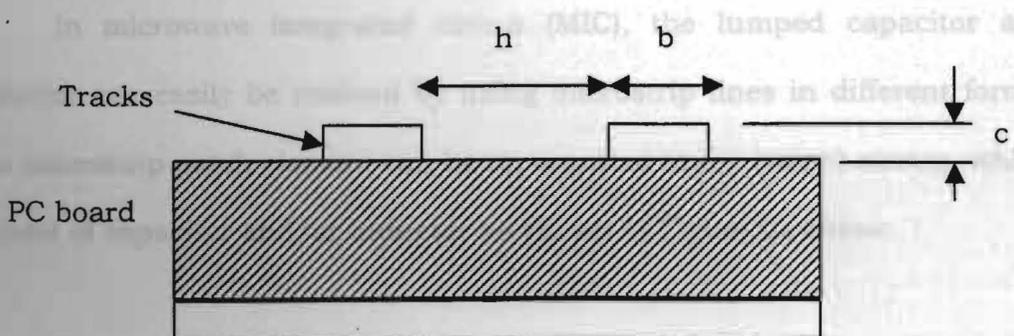
The transmission line is only partially filled with dielectric material, with the material being between the strip and an infinite ground plane.

Using microstrip line is like getting the transmission line for free, as part of the board layout. The specific dimensions of the traces are calculated using various formulas, to give the desired characteristic impedance. A wide range of Z_0 values can be designed by varying the line dimensions. The practical range of microstrip impedance is between 50 and 200 ohms, typically, but the values can be outside this range by careful choice of key dimensions.

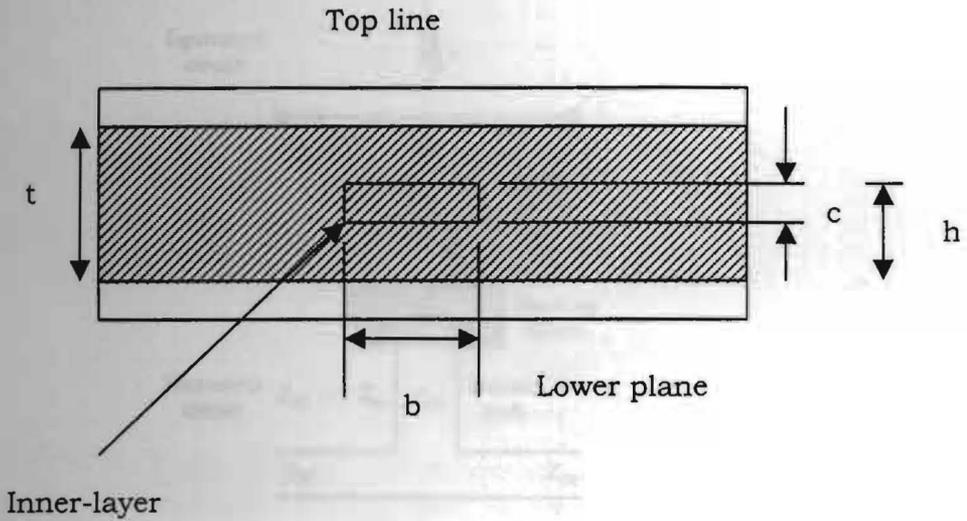
Several different microstrip configurations are in common use, and many other configurations are possible.



$$Z_0 = 87 / (\epsilon + 1.41)^{1/2} \ln \{ 5.98h / 0.8b + c \} \Omega$$



$$Z_0 = 120 / \sqrt{\epsilon} \ln \{ \pi h / (b + c) \} \Omega$$



$$Z_0 = 60 / \sqrt{\epsilon} \ln \{ 4t / 0.67\pi b (0.8 + c/h) \} \Omega$$

2.2 Microstrip Line Realization

From transmission line theory, an open-circuited termination is equivalent to a capacitor and a short-circuited termination is equal to an inductance when the line is very short.

In microwave integrated circuit (MIC), the lumped capacitor and inductor can easily be realized by using microstrip lines in different forms. The microstrip patch element can be represented in equivalent circuit, which consist of capacitor and/or inductor as shown in Figure 2a below.

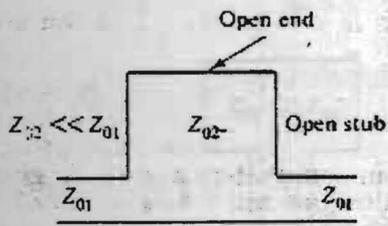
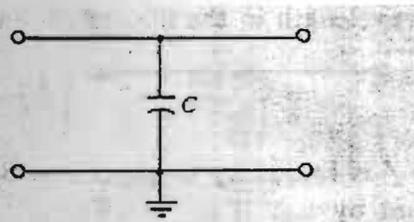
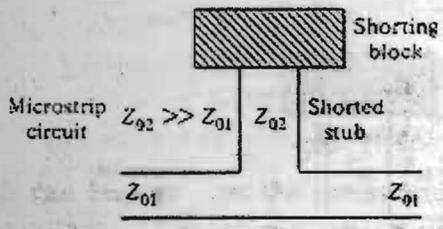
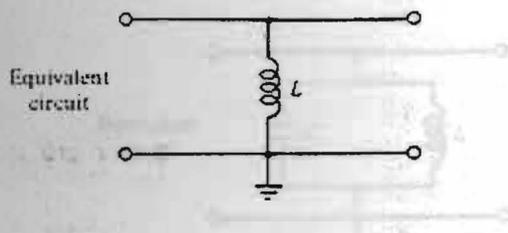


Figure 2a. Realization of microstrip-line circuit.

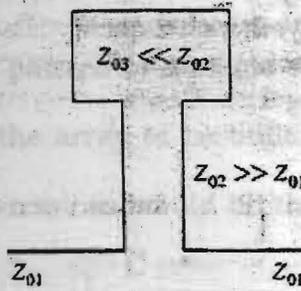
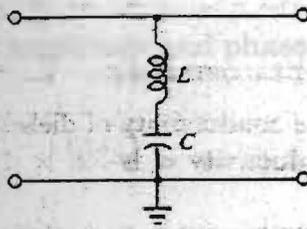
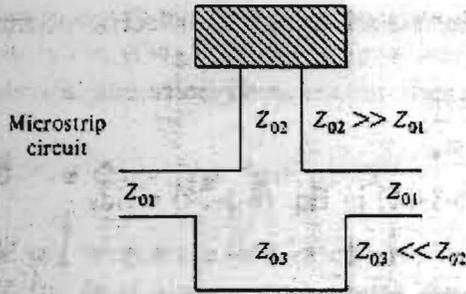
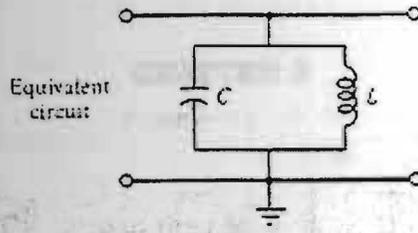


Figure 2a: Realization of microstrip-line circuit.

CHAPTER 3

LITERATURE REVIEW

3.1 Array definition

An array of antenna elements is a spatially extended collection of N similar radiators or elements, where N is a countable number bigger than 1. The term of "similar radiators" means that all the elements have to be spaced on a regular grid, neither do they have to have the same terminal voltages. It is assumed that they are all fed with the same frequency and that one can define a fixed amplitude and phase angle for the drive voltage of each element.

3.2 Element and Array Pattern

The polar radiation pattern of a single element is called the element pattern. It is possible for the array to be built recursively; for instance the element may itself be an array, as would be the case if we had an array of Yagi-Uda antennas.

The array pattern is the polar radiation pattern which would result if the elements were replaced by isotropic radiators, having the same

amplitude and phase excitation as the actual elements, and spaced at points on a grid corresponding to the far field phase centres of the elements. it has

3.3 Pattern Multiplication

If all the polar radiation patterns of the elements is assumed to be identical (within a certain tolerance) and the patterns are aligned in the same direction in azimuth and elevation, then the total array antenna pattern is got by multiplying the array pattern by the element pattern.

3.4 Calculation of array pattern

The radiated field strength at a certain point in space, assumed to be in the far field, is calculated by adding the contributions of each element to the total radiated fields. The field strengths fall off as $1/r$ where r is the distance from the isotrope to the field point.

3.5 Impedance matching

An imaginary joins between the left half and the right half is made along a very long length of transmission line. The right half presents a real lossless impedance (equal to the characteristic impedance) to waves approaching the junction from the left half. There is no actual discontinuity at the imaginary join, thus there is nothing to give rise to a reflection here.

If the right half transmission line is replaced with a resistor having resistance equal to the real lossless characteristic impedance of the line,

there is no way the waves arriving at the junction can tell the difference between the resistor and the long right-half transmission line it has replaced. Thus, there can be no reflection.

All the power delivered by the generator is dissipated in the resistance and there is no reflected wave amplitude or power as well as the backward travelling wave. As far as the generator is concerned, there is no way it can know how long the length of the line is. It cannot tell the difference between a resistive load Z_0 and a very long matched line having characteristic impedance Z_0 .

3 methods which may be used in the automatic generation

3.1.1. Coordinatograph.

Coordinatograph usually represents a more sophisticated version of the hand drawn manually operated counterpart. It can be looked upon as a plotting device drawing pen replaced by a cutting tool like knife. Coordinatograph also consists of a base plate above which a cutting tool is placed at both x and y coordinates. A film consisting of two layers is usually placed on the base plate, i.e. a transparent layer with an opaque upper layer. A special knife is then moved onto the film so that it just penetrates the opaque film layer. As it is moved along, the film will be cutting the required pattern. Coordinatograph usually interfaced with a computer which then controls the knife position.