Characteristic Multimode SIW Filter and Microstrip Antenna Square Patch

Rosmawati Binti Othman[1], Dr.Aziati Husna Binti Hj Awang[2]

Faculty of Electrical Engineering,University Teknologi MARA, Shah Alam, Malaysia

[1]eros6176@yahoo.com.my

[2]aziatihusna@salam.uitm.edu.my

***Abstract*—**In this paper, Substrate Integrated Waveguide (SIW) microstrip antenna and filter is proposed a detailed study of how to design a microstrip square patch antenna with enhanced directive gain. A uniform slotted SIW in circular filter is designed using multilayer technology with multimode at the common ground plane.The proposed SIW is simulated and anlyzed using CST microwave studio suite software. Simulation and measured results proposed in S-band at frequency from 2 to 4 GHz. This antenna is feed by a 50Ω microstrip line offset from the centre of a square.

***Keywords*—** Substrate Integrated Waveguide (SIW), multimode, directive gain

I. Introduction

In the past few decades, wireless communications field has experienced revolutionary growth. This was happened due to services and creation of products as Bluetooth, wireless telephone handsets, wireless local Position System (GPS), wireless local area networks, and etc,. In a fact, the basic components of wireless devices are filters and antennas plays an important role. Therefore, the need for low-profile filter small size and antenna with highly efficient that can be applied in wireless products is essential. Furthermore, the subsystem design in multi-layer technology can further reduce the overall size instead of using the classical approach to the basic functions [1].

The substrate integrated waveguide (SIW) is a new generation form of transmission lines that have been popularized in recent years by several researchers. It consists of a rectangular or square synthetic electromagnetic waveguide formed in a rectangular or square solid dielectric substrate by arraying Metallized office or through hole metal plate connecting the lower and upper substrates. This waveguide can be easily designed with through-hole technique for the mass production of low cost.

In high frequency applications, microstrip device is not efficient due to the waves at high frequencies is small but microstrip device manufacturing requires very tight tolerances. Means at high frequency waveguide devices used, found too difficult manufacturing process. Hence, a new concept emerged known as the substrate integrated waveguide is introduced. SIW is a transition between dielectric-filled waveguide (DFW) and microstrip. Dielectric waveguide has received little attention to the millimeter wave circuit design and microwave. This is because it has two basic problems, ie, capital difficult transition to a planar circuit, and the damage caused by the discontinuity of the radiation. Non-radiating dielectric (NRD) waveguide [2] is proposed to solve many of the shortcomings of dielectric waveguide loss associated with radiation

There is growing interest in the integration of microwave filters and antennas in the RF communication system [3-4]. In practice, filters and antennas that have been designed separately which are linked together in a common reference impedance, 50Ω. The S-band is part of the microwave band of the electromagnetic spectrum. It has been defined by the IEEE standard for radio waves with frequencies that range from 2 to 4 GHz, crossing the conventional boundary between SHF and UHF at 3.0 GHz. S-band is used by surface ship radar, weather radar, satellite communications and some, especially communication mainly used by NASA to communicate with the International Space Station and Space Shuttle.

Fig. 1, shows a family of substrate integrated waveguiding structures identified and the most popular is SIW because for easy fabrication and similar in electrical and mechanical with respect to the rectangular waveguide conventional also shows for various microwave and millimeter wave applications from several GHz to THz [5- 8].

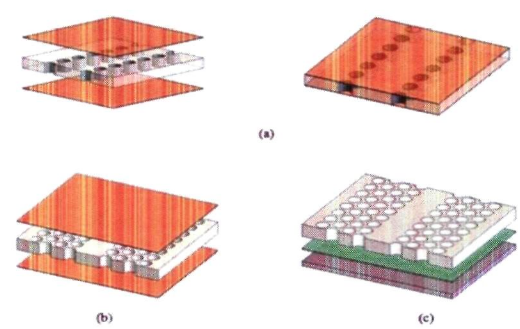


Fig. 1. Synthesized SIW

Fig. 1: Typical examples of synthesized substrate integrated waveguiding structures compared to their original non-planar versions:

a) substrate integrated waveguide (SIW)
b) substrate integrated non-radioactive dielectric (SINRD) guide
c) substrate integrated image guide (SIIG)

In this paper, proposed design in Substrate Integrated Waveguide (SIW) microstrip antenna and filter is shown in Fig. 2.

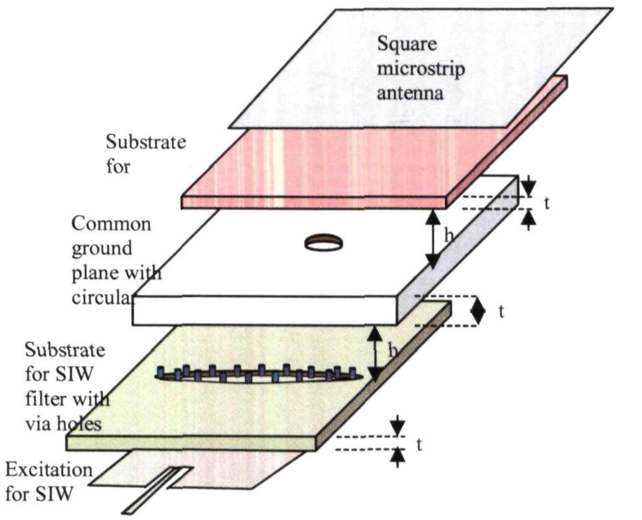


Fig. 2: Proposed circular iris integrated SIW microstrip antenna and filter

A square shape microstrip antenna layered on top SIW filter and share the same common ground plane. A circular iris is located at the ground plane for the pair of antennas and filters [9-10] where the focus is centered on the different types of multimode shapes. The proposed integrated filter and antenna operating at 2 GHz. SIW is an artificial waveguide which is constructed on a planar substrate with periodic arrays of via holes [17] in a single circular SIW cavity with an angle, $\alpha = 180^0, 90^0, 67.5^0, 45^0, 22.5^0$ and 11.25^0. Meanwhile, set the equivalence via holes between the SIW cavities.

The rule of the design of the square SIW filter by the resonant frequency from the metalized via holes diameter, *d* and pitch, *p* can be calculated using the equations

$$d > 0.2\,\lambda_o \qquad , d/p \leq 0.5$$

where ; $\lambda_o = c/f$, free space wavelength

Microstrip patch antennas can be fed by a variety of methods [11-12]. These methods can be classified into two categories: non-contacting and contacting. In the non-contacting method, the electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. In the contacting scheme, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. Four of the most popular feed techniques used are the microstrip line (Fig.2), coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes) [14-15]. This paper uses microstrip line feeding technique [16].

II. SIW SQUARE PATCH PARAMETER

Design of SIW depends mainly upon three parameters, namely substrate and its dielectric constant, ε_r, height of the substrate, h and resonant frequency, f_r. In this paper, parameters are :

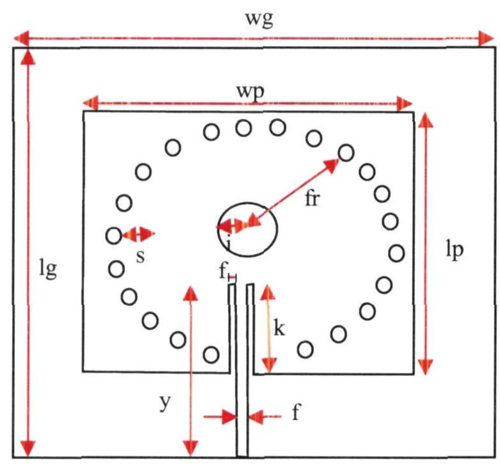


Fig. 3: Dimensions at top of Proposed integrated SIW microstrip antenna and filter

Resonance frequency, f_r = 2 Ghz, Dielectric constant, ε_r = 10.2, Height of total substrate thickness of the entire integrated microwave antenna and filter, h = 2.05mm . SIW proposed design is carried out by CST Microwave Studio software. The chosen material is Rogers Duroid 6010 and Cooper were can be loaded from CST software library. The width, length and other parameter of patch can be found out by design equation given by reference book of patch antenna [11-13]:

1) *Calculation of Width (W):*

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

The calculated width of proposed square patch antenna from equations (1) is W = 59.2927 mm, where c is speed of light = 3 x 10^8 m/s [10, 11].

2) *Calculation of the effective dielectric constant:*

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 10\frac{h}{W}\right]^{1/2} \qquad (2)$$

The calculated effective dielectric constant from equation (2) [11], ε reff = 2.1335

3) *Calculation of the effective length of patch:*

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \quad \text{--------------------------- (3)}$$

From above equation the effective length is comes out to be [11,13], L_{eff} = 51.3469 mm

4) *Calculation of the length extension:*

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \quad \text{------------------- (4)}$$

Which comes out to be [11, 12] ΔL = 0.8276 mm.

5) *Calculation of the resonant length of patch (actual length)*

$$L = L_{eff} - 2\Delta L \quad \text{--- (5)}$$

This comes out to be, L = 50.5192 mm

6) *Ground plane dimensions:*

$$L_g = 6h + L$$

$$W_g = 6h + L$$

For square patch dimension, Wp = Lp and Wg = Lg

Where,

Wp = width of patch
Lp = width of length
Wg = width of ground
Lg = width of ground

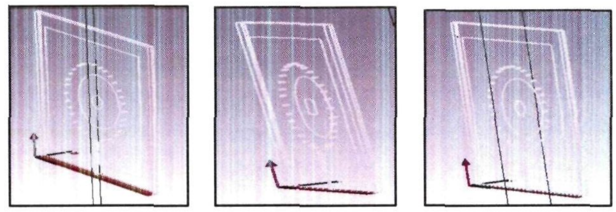
Inset feeding structure was used to feed the filter. The geometric parameters of the proposed integrated SIW microstrip antenna and filter in Fig. 2 and Fig. 3 are listed in Table 1.

TABLE 1:
GEOMETRIC DIMENSIONS OF PROPOSED RADIATING FILTER

Parameter /Symbol	Value (mm)
Thickness of the microstrip antenna and the excitation copper (t1)	0.035
Thickness of common ground plane (t2)	0.07
Thickness of filter substrate (h1)	1.27
Thickness of antenna substrate (h2)	0.64
Radius of filter(fr)	18.3
Radius of iris (i)	3.24
Gap between filter – antenna (s)	8.56
Feed of microstrip (y)	23.71
Feed patch (k)	11
Width of feed (f)	1.15

III. SIW DESIGN

Three types of multimode have been designed namely circular iris, square iris and cross iris as shown in Fig. 4.



a) Circular iris b) Square iris c) Cross iris

Fig. 4: Three types of multimode located at the common ground plane

The parameters are the same except at common ground plane. A slotted waveguide has no reflector but released directly through the slot. Slot spacing is critical and can be multiple by the wavelength used for transmission and reception. The size and location through the hole measured as containing an electromagnetic field in the substrate integrated waveguide with negligible leakage losses and substrate integrated waveguide having the same propagation constant and characteristic impedance as square waveguide equivalent [13].

IV. RESULT AND DISCUSSION

The proposed SIW microstrip antenna and filter has been designed and simulated using CST microwave studio suite software.

A. *Return Loss (S_{11}) and bandwidth*

Fig. 5 shows the variation of return loss with frequency. The plot shows the resonant frequency in GHz and a minimum return loss, S11 are available at the resonant frequency with narrow bandwidth was plotted. Return loss with a negative sign is called the reflection coefficient (Γ).

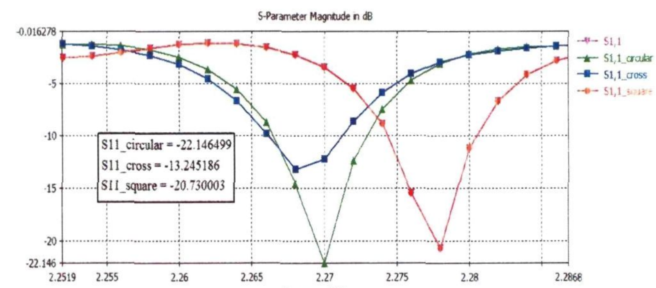


Fig. 5: Return Loss vs Frequency

The proposed SIW microstrip antenna and filter in S band at resonant frequency, f_r = 2.27 GHz. A very good return loss of -13.245 dB found in cross iris is obtained for this structure compared with 2 irises.

At this resonant frequency, bandwidth with 3 types of irises as shown in Table 2:

TABLE 2: COMPARISON OF BANDWIDTH

Iris	Bandwidth		Bandwidth (GHz)
	Max	Min	
Circular	2.273	2.2664	6.54
Square	2.2805	2.2744	6.2
Cross	2.2713	2.2661	5.179

TABLE 3: COMPARISON OF GAIN AND DIRECTIVITY

Iris	Gain (dB)	Directivity (dBi)
Circular	-6.862	3.130
Square	-7.504	-0.3587
Cross	-7.933	-19.22

B. *Voltage Standing Wave Ratio (VSWR)*

The VSWR for proposed design of microstrip square patch plot is as shown in Fig. 6.

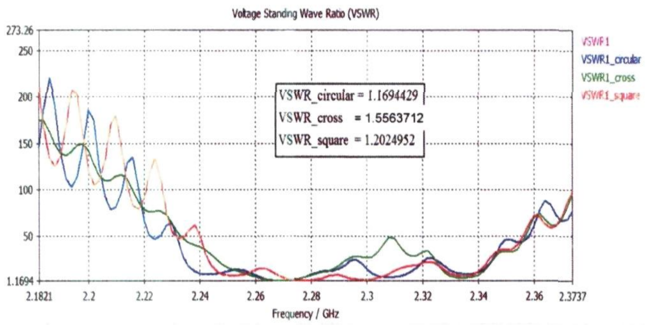


Fig. 6: VSWR vs Frequency

The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the proposed SIW is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.1694dB found on circular iris, where VSWR at the antenna match is considered very good and little would be gained by impedance matching. Reflection coefficient, $\Gamma = 0.08$, reflected power = 0.6%, reflected power = -22.15 dB and mismatch loss = 0.03 dB comparing with 2 irises with reflected power 0.8 % for square iris and 4.7% for cross iris.

Return loss (Fig. 5) is related to standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high.

C. *Total Gain and Directivity*

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting or to receive energy better from a particular direction when receiving. There is a relationship between gain and directivity. The results for proposed microstrip square with multimode irises attached at common ground plane are shown in Table 3

V. CONCLUSIONS

The proposed integrated SIW microstrip antenna and filter square patch has been analyzed using CST microwave studio suite software for the varying multimode at the common ground plane working in S-band. From analysis, found the circular iris is good designed with gain is -6.862 dB, and directivity is 3.130 dBi comparing with 2 irises and results for VSWR is 1.1694 dB, return loss is -22.1464 dB. It is interesting to note that the highest gain performance is exhibited by the circular iris backed by circular cavity structure. A circular iris tend to give better bandwidth. A directional antenna may have good gain in one direction and poor gain in others. The poor gain may come from the pattern shape, poor match, internal losses or external loading. This depends on the antenna and the application.

Detailed experimental studies can be taken up at a later stage to fabricate the microstrip antenna and filter. Before going for fabrication we can optimize the parameters of antenna using one of the soft computing techniques.

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