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Design and Simulation of Broadband Rectangular Microstrip Antenna

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Abstract

In this work, many techniques are suggested and analyses for rectangular microstrip antenna (*RMSA*) operating in *X-band* for *10 GHz* center frequency. These approaches are: *lowering quality factor, shifting feeding point, using reactive loading and modification of the patch shape.*

The design of a *RMSA* is made to several dielectric materials, and the selection is based upon which material gives a better antenna performance with reduced surface wave loss. *Duroid 5880* and *Quartz* are the best materials for proposed design to achieve a broader Bandwidth (BW) and better mechanical characteristics than using air. The overall antenna BW for RMSA is increased by 11.6 % with *Duroid 5880* with shifted feeding point and with central shorting pin (Reactive loading) while that for *Quartz is 17.4 %.*

***Modification* of patch shape with similar improving techniques gives an overall increasing VSWR bandwidth of *26.2 %* for *Duroid 5880* and a bandwidth of *30.9 %* for *Quartz*. These results are simulated using *Microwave Office* package version 3.22, 2000.**

الخلاصة

يقدم هذا البحث عدة تقنيات لتوسيع حزمة التردد لعمل الهوائي الشريطي الدقيق ذو الشكل المستطيل والذي يغذى من نقطة واحدة , بحيث يكون عمله في الحزمة الترددية *X* و بتردد مركزي قدره (*10 GHz*) وتضاؤل تاثير الموجة السطحية الى ادنى المستويات. وهذه التقنيات هي : تقليل معامل الجودة للهوائي (*Q*) و تغيير موقع نقطة التغذية واستخدام الحمل غير الفعال و تعديل الشكل للهوائي.

لقد تم تقديم عدة نماذج تصاميم للهوائي الشريطي الدقيق ذو الشكل المستطيل لعدة مواد عازلة , و قد تم اختيار التصميم الذي اعطى افضل اداء للهوائي مع تقليل نسبة الخسائر بسبب تاثير توليد الموجة السطحية, كانت افضل مادتين للتصميم المعتمد هما ال (*Quartz*) و ال (*Duroid5880*) , حيث ان هاتين المادتين اعطت اوسع حزمة عمل ترددي من المواد الاخرى وكذلك افضل بخواصها الميكانيكية .

لقد اعطىالهوائي الشريطي الدقيق ذو الشكل المستطيل مع مادة ال (*Duroid5880*) زيادة عرض حزمة اشتغال ترددي كلي بمقدار (*11.6 %*) , اما تلك مع مادة ال (*Quartz*) فقد كانت الزيادة بعرض حزمة الأشتغال بمقدار (*17.4 %*). اما تقنية تعديل الشكل للشريحة الدقيقة لهوائي (*Duroid5880*) قد اعطى زيادة عرض حزمة بمقدار (*26.2 %*) و (*30.9 %*) لهوائي (*Quartz*) .

تم استخدام برنامج المحاكاة (Microwave Office Package ver. 3.22, 2000) لمحاكاة النتائج.

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1. Introduction

The arrangement of an arbitrary shaped patch microstrip antenna is given in Figure 1. It consists of patch, substrate, ground plane and feeding point. A patch is a two-dimensional antenna element, which is often rectangular in shape. It is of a very thin thickness (*t*) of metallic strip on top of a material known as the substrate with thickness h ($h«\lambda_o$, usually $0.003\lambda_o \le h \le 0.05\lambda_o$, where λ_o is free space wavelength) above a ground plane[1].The microstrip antenna (MSA) can be excited directly either by a coaxial probe or by a microstrip line. It can also be excited indirectly using electromagnetic coupling or aperture coupling and a coplanar waveguide feed, in which case there is no direct metallic contact between the feed line and the patch. The microstrip patch is designed so that its pattern has maximum normal to the patch plane (broadside radiator) by choosing a certain field configuration mode. For rectangular patch, the length *L* of the element is usually $\lambda_o/3<L<\lambda_o/2$. The strip (patch) and the ground plane are separated by a dielectric (substrate).

Microstrip antennas have a very high antenna quality factor (*Q*). This factor represents the losses associated with the antenna and a large quality factor leads to narrow bandwidth and low efficiency. Quality factor can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by the use of photonic bandgap structures [2]. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements. The patch is generally square, rectangular, circular, triangular, and elliptical or some other common shapes .

Microstrip antennas have narrow bandwidth, typically *1-5%*, which is the major limiting factor for the widespread application of these antennas. Increasing the bandwidth of MSA has been the major thrust of researches in this field [3,4].

2. Analyses and Modeling of RMSA

Three methods of analysis are commonly used to calculate microstrip antenna (MSA) parameters [5,6]. These are:Transmission line model, cavity model, and full wave analysis.

It is useful to model the microstrip antenna as a transmission line . This model is the simplest of all and it gives good physical insight but it is less accurate. It represents the *MSA* by two slots of width *W* and height *h,* separated by a transmission line of length *L*. The microstrip is essentially a non homogeneous line of two dielectrics, typically the substrate and air. An effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The expression for ε_{reff} is given by [1]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad \ldots\ldots (1)$$

Fig. 2 shows a *RMSA* of length *L,* width *W* resting on a substrate of height *h.* The co-ordinate axis is selected such that the length is along the *y* direction, width is along the *x* direction .

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than *λ/2* where *λ* is the wavelength in the dielectric medium and is equal to $\lambda_o/\sqrt{\varepsilon_{reff}}$ where λ_o is the free space wavelength.

In Fig. 2a, the *MSA* is represented by two slots, separated by a transmission line of length *L* and open circuited at both ends. Along the width of the patch, the voltage is max and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane as in Fig.2b.

The dimensions of the patch along its length have now been extended on each end by a distance Δ*L*, which is given empirically by [7]:

$$\Delta L = 0.412 \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \text{h} \quad \ldots (2)$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L \quad \ldots (3)$$

For a given resonance frequency f_o, the effective length is given as:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} \quad \ldots (4)$$

Where c is the speed of light.

For a rectangular Microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}} \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2 \right]^{\frac{1}{2}} \quad \ldots (5)$$

Where *m* and *n* are modes along *L* and *W* respectively.

For efficient radiation, the width *W* is given as [8] :

$$W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad \ldots (6)$$

The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling .

The four most popular feed techniques used in MSA are the microstrip line, coaxial probe , aperture coupling and proximity coupling [1, 7].

The input impedance should be accurately known so that a good match between the element and the feed can be designed. Referring to Fig. 3, the input impedance at the feed point (x_o) is [1,9]:

$$Z_{in}(x_o) = \frac{1}{G_r + G_m \cos(n\pi)} \cos^2(\beta x_o)$$

Where G_r is the self conductance given by the following three relations, depending on W/λ_o :

$$G_r = \frac{W^2}{90\lambda_o^{\,2}}, \qquad for\ W<0.35\lambda_o$$

$$G_r = \frac{W}{120\lambda_o} - \frac{1}{60\pi^2}, \qquad for\ 0.35\lambda_o \le W \le 2\,\lambda_o$$

$$G_r = \frac{W}{120\lambda_o}, \qquad \text{for } 2\lambda_o \le W$$

and G_m is the mutual conductance between the patch ends. At resonance and $G_r >> G_m$ then the input impedance becomes:

$$Z_{in}(x_o) = R_{in} = \frac{1}{G_r}\cos^2\left(\frac{\pi}{L}x_o\right) \quad \text{.... (7)}$$

A microstrip antenna is basically a broadside radiator, which has a relatively large beam width and low gain characteristics. The formulas for the *E* and *H* plane radiation patterns are given by [10]:

E-plane:

$$F(\Phi) = \{\sin[(k_o h/2)\cos\Phi] / (k_o h/2)\cos\Phi\}.\cos[(k_o L/2)\cos\Phi] \quad \text{.... (8)}$$

H-plane:

$$F(\theta) = \{\sin[(k_o w/2)\cos\theta] / (k_o w/2)\cos\theta\}.\sin\theta \quad \text{.... (9)}$$

Where: $k_o = 2\pi/\lambda_o$ (free space wave number)

The half power beam widths in the *H* and *E* planes are given by [11]:

$$\theta_{BH} = 2\cos^{-1}\left[\sqrt{\frac{1}{2 + k_o W}}\right] \quad \text{..... (10)}$$

$$\theta_{BE} = 2\cos^{-1}\left[\sqrt{\frac{7.03}{3k_o^2 L_e^2 + k_o^2 h^2}}\right] \quad \text{..... (11)}$$

Thus beam width can be increased by choosing a smaller element, thus reducing *W* and *L*. For a given resonant frequency these dimensions may be changed, by selecting a substrate having a higher relative permittivity. As beam width increases, element gain and directivity decrease, however, efficiency is unaffected .

The expression for approximately calculating the directivity *D* of the rectangular microstrip antenna is given by [10] :

$$D \cong 0.2W + 6.6 + 10\log\left(1.6/\sqrt{\varepsilon_r}\right) \text{ dB} \quad \text{....... (12)}$$

For other geometries, the values of equivalent *W* can be obtained by equating its area with that of the rectangular microstrip antenna [12].

The most serious limitation of the microstrip antenna is its narrow *BW*. The *BW* could be defined in terms of its *VSWR* or input impedance variation with frequency or in terms of radiation parameters. For the circularly polarized antenna, *BW* is defined in terms of the Axial Ratio .

VSWR is a very popular parameter for determining the *BW* of a particular antenna configuration($1 \le VSWR \le 2$)

as an acceptable interval for determining the BW of the antenna.

BW is presented more concisely as a percentage where:

$$BW\ \% = \frac{\Delta f}{f_o} \times 100\ \%$$

…. (13)

Where Δf is the width of the range of acceptable frequencies, and f_o is the resonant frequency of the antenna [10].

The expressions for approximately calculating the percentage BW of the *(RMSA)* antenna in terms of patch dimensions and substrate parameters is given by[13]:

$$\% BW = \frac{A \times h}{\lambda_o \sqrt{\varepsilon_r}} \sqrt{\frac{W}{L}}$$

…. (14)

Where A is constant:

A = 180 for

$$\frac{h}{\lambda_o \sqrt{\varepsilon_r}} \leq 0.045$$

A = 200 for

$$0.045 \leq \frac{h}{\lambda_o \sqrt{\varepsilon_r}} \leq 0.075$$

A = 220 for

$$\frac{h}{\lambda_o \sqrt{\varepsilon_r}} \geq 0.07$$

With an increase in W, bandwidth increases. However, W should be taken less than λ to avoid excitation of higher order modes.

The BW of the *(MSA)* can also inversely proportional to its quality factor Q and is given by [1].

$BW=(VSWR-1)/(Q\sqrt{VSWR})$ …. (15)

The BW is usually specified as frequency range over which $VSWR \leq 2$.

3. Design considerations and Process of Broadband MSA

The methods for increasing the BW of *(MSA)'s* are continuously getting upgraded. The search for an ideal broadband *(MSA)* is still continuing. Perhaps a combination of various approaches would lead to an optimum broadband configuration [3,5].

There are various techniques for increasing the bandwidth BW of *(MSA)'s*. The main techniques used to increase the bandwidth are presented briefly as[14]:

a) Low Quality Factor :

The principle of introducing low quality factor of the cavity below the patch can be achieved by:

. Low dielectric constant .

. Larger thickness of the substrate but it is restricted by the surface wave generation leading to low gain and low efficiency of the antenna .

b) Modified Shape Patches :

The regular *(MSA)* configurations, such as rectangular and circular patches have been modified to rectangular ring and circular ring, respectively, to enhance the BW. The larger BW is because of a reduction in the quality factor of the patch resonator, which is due to less energy stored beneath the patch and higher radiation. In this work the modified shape is developed as a compact model; it has nearly a trapezoidal shape, its dimension consist of a combination from three rectangular patches one at resonance (center frequency of the operating band) which gives the length of the patch and the other two at beginning frequency and end frequency of the operating bandwidth which gives the two widths of the trapezoidal shape[12].

c) Multilayer Configurations :

In the multilayer configuration, two or more patches on different layers of the dielectric substrate are stacked on each other. Based on the coupling mechanism, these configurations are categorized as electromagnetically coupled or aperture-coupled microstrip antennas [12].

The design process of broadband MSA is based mainly on the measurements acquired from the narrowband rectangular antenna using single layer configuration. The antenna is assumed passive, linearly polarized, fed by a coaxial probe with input impedance nearly of *50 ohms*. The patch antenna element is designed to radiate or operate with a narrow impedance bandwidth.

The narrow bandwidth of the microstrip antenna can be widened by using combination between lowering Q-factor, modified shaped patches, and reactive loading approaches.

To achieve the broad banding of the microstrip antenna, it is important to determine the requirement arises with such design. The requirements needed to start the design process of a broadband microstrip antenna are:

a- Type of substrate material to be choosen.

b- The center frequency, and

c- The operating bandwidth.

The substrate material is important in the successful design, where a low quality factor of the cavity below the patch can be achieved by proper choice of the substrate material. The center frequency of the antenna is *10 GHz* designed to operate at whole *X-band* .

The substrate height is limited by the excitation of surface wave, and then choice is based on Woods criterion which depends on the operated frequency and substrate material [7]:

$h<0.07\lambda_o$ for $\varepsilon_r \approx 2.3$, and $h<0.023\lambda_o$ for $\varepsilon_r \approx 10$

Assuming the antenna is operating to cover the whole *X-band* range from *8 GHz* to *12 GHz*. For each frequency there is a desired substrate height associated with it. This height is based on the above criterion. For f = 12 GHz then $\lambda_o = 2.5$ cm , the calculated heights for both dielectrics are:

$h = 0.07\ \lambda_o = 0.175$ cm for $\varepsilon r \approx 2.3$, and $h = 0.023\lambda_o = 0.0575$ cm for $\varepsilon r \approx 10$.

Therefore for $\varepsilon_r \approx 2.3$ the height must be *0.175 cm* or less, and for $\varepsilon_r \approx 10$ the height must be *0.0575 cm* or less. For proper design, the choice is made for $\varepsilon_r \approx 2.3$ is *0.17 cm* and for $\varepsilon_r \approx 10$ is 0.057 cm, since the antenna is assumed to cover the *X-band*, i.e. to stay in the safe side if antenna is operating in the upper frequency limit at *12 GHz*.

The flow chart in Figure 4 explains the design process. During *phase 1* of the work, the permittivity of the substrate will be tested. This process had to be carried out several times to reach an optimal value of substrate permittivity that gives a wider BW using accurate permittivity values. Phase one also oversaw the selection of substrate heights to reduce surface wave excitation. In phase two, three narrowband patches were designed. The first one was at the center frequency of the band, the second was at the beginning frequency of the band

and the third one was at the end frequency of the band. The patches were thoroughly tested for bandwidth and tuned to best match the input impedance. Phase three involved in-depth research regarding possible broadband techniques. The best scheme is chosen based on manufacturing simplicity without compromising performance over the frequency band concerned. The modified patch has nearly a trapezoidal shape as shown in Fig. 5 with its new dimensions .

The feeding point is the same as that point of the patch at the beginning frequency of the band, with some amount of offset to match Z_{in} .

Central pin may improve the purity of the resonant mode. An addition of a shorting pin acts as an extra parameter to control the mode excitation.

4. Design Examples [15]

To achieve the requirements, two design examples are considered for *X-band* applications. The patch antenna element is designed to operate at *10 GHz* as center frequency, and to widen the bandwidth as far as possible to cover *X-band*. The calculations are made step by step from dielectric materials that have low dielectric constant to higher one.

Example one**:** Rectangular patch design, dielectric material *RT Duroid 5880*, dielectric constant $\varepsilon_r=2.2$, *loss tangent<0.0009*, *operating frequency=10 GHz*, $\lambda_o=3$ *cm.*

- The height (h) must be less than *0.175 cm* for $\varepsilon_r \approx 2.3$. Then height should be *h=0.17 cm.*
- The width of the MSA is given by equation (6), where *W=1.1859 cm*
- Eqn(1) gives the effective dielectric constant as $\varepsilon_{reff}=1.9638$
- Eqn (4) gives the effective length as: $L_{eff}=1.0704$ *cm*
- Eqn (2) gives the length extension as: $\Delta L=0.0864$ *cm*

The actual length is obtained from eqn (3) as:

$L = L_{eff} - 2\Delta L$ *then* $L=0.8976$ *cm*

The ground plane dimensions are $L_g=1.9176$ *cm and* $W_g=2.2059$ *cm*

Feed point location where the input impedance is nearly *50 ohms* is: $X_f = W/2$ and $Y_f = L/(2\sqrt{\varepsilon_{reff}})$ then $X_f=0.593$ *cm along the width, and* $Y_f=0.320$ *cm along the length.*

- Eqns (8) and (9) give the *E* and *H* plane radiation patterns: $k_o=2\pi/\lambda_o=2.1$ *rad/cm*
- The half power beamwidths are given by eqns (10) and (11) as: $\theta_{BE}=1.65$ *rad and* $\theta_{BH}=2.158$ *rad*
- The directivity is calculated from eqn(12) as: $D= 6.933$ *dB*
- Eqn (14) gives the *BW* as: *BW=7.9 %*

This example can be extended for all other materials. Table 1 gives the calculated parameters associated with such materials.

It is clear from this table that Duroid 5880, Duroid 5870 and, Quartiz are the best materials for proposed design with broader bandwidth and better mechanical characteristics than using air.

Example two : Modified Shape Microstrip Design (MSMSA)[16].

Dielectric material *RT Duroid 5880*, dielectric constant $\varepsilon_r=2.2$, *loss tangent<0.0009*, *operating frequency (8-12) GHz*, $\lambda_o=3$ *cm*, $h=0.17$ *cm.*
From Figure 4 broadband antenna design needs to choose L, W_1 and W_2. This can be done by the following steps design procedure:

From Table 1, the actual length L at *10 GHz* for this dielectric is

$L=0.8976$ *cm*

- Eqn (6) gives W_1 at *8 GHz* $W_1=1.48232$ *cm* and W_2 at *12GHz*

$W_2=0.988212$ *cm*

- The feed point location as:

$X_f=W_1/2=0.74116$ *cm*, and $Y_f=L/2\sqrt{\varepsilon_{reff}}=0.320$ *cm*

- The ground plane dimensions as:

$L_g=6h+L=1.9176$ *cm*, and $W_g=6h+W_1=2.50232$ *cm*

Table 2 shows the calculated dimensions for different materials compared to air case. This table is used to get all results for MSA performance.

5. SIMULATION AND RESULTS

In this section, a documentation of results is presented. These results are obtained by using a design package called *Microwave Office* version 3.22, 2000. The microwave office results are compared with their corresponding theoretical results. These results are separated into two categories: The first category includes the simulation and test of *RMSA* with single layer, probe fed and its performance calculations (*VSWR*, bandwidth, *HPBW* and, field pattern). While the second category, includes the simulation and test of the suggested modified shape microstrip antenna *(MSMSA)* and the effect of variation of the feeding point with and without adding the central shorting pins[15].

a) Consider the *RMSA* that were designed in previous sections, and whose results were given in Table 1, are tested using microwave office package .

The selection of the correct material for the broadband design is made. Three types of substrate materials are chosen. These substrate materials are *Duroid 5880, Quartiz, and Duroid 6006* and their dielectric constants are *2.2, 3.78* and *6.15* respectively. The test shows that the bandwidth (*for VSWR*≤2) in the operating X - band, for *Duroid 5880* is *9.7%* and for *Quartiz* is *15.5%*, while for *Duroid 6006* it is *1.3% [15]*. Therefore the choice was made on *Duroid 5880* and *Quartiz*, because they have a broader *BW* than *Duroid 6006*.

Referring to Table 1, the original feeding point of *RMSA* with substrate material *Duroid 5880* is (X_f = 0.593 *cm*, Y_f= 0.320 *cm*) and, for *Quartz* is (X_f = 0.34 *cm*, Y_f = 0.25 *cm*) with an operating frequency of *10 GHz*. The feeding will be shifted along *X* and *Y* axis. From the original feeding point, for *Duroid 5880* it is by amount of ±*0.038952 cm* along *X* and ±*0.044118 cm* along *Y*, and for *Quartz* it is by amount of ±*0.048515 cm* along *X* and ±*0.034425 cm* along *Y*.This shifted gives a gain in the *BW* of the *RMSA* , for *Duroid 5880*, it is enhanced from *(9.7%)* to *(10.8%)*. While for *Quartz*, the *VSWR BW* is enhanced from *(15.5%)* to *(16.1%)*. The optimum value of shifting for *Duroid 5880* is toward positive *X*, while for *Quartz* it is toward negative *X taking into* *consideration the* mismatching problems.

The central shorting pin is added to the rectangular patch, where its feeding position is shifted. As can be seen from Fig. 6 , there is a gain in *VSWR BW*≤2 of the *RMSA*, when the central shorting pin is used, because the resonance size of the patch increases. For substrate material *Duroid 5880* is enhanced the bandwidth from *1080 MHz (10.8%)* to *1160 MHz (11.6%)* . It increases by an amount of *80 MHz (0.8%)*. While that *for Quartz, the BW* is enhanced from *1610 MHz (16.1%)* to *1740 MHz (17.4%)*. It increases by an amount of *130 MHz (1.3%)*.

Figure 7 a,b shows the normalized electric field in polar and rectangular plots radiation pattern of the *RMSA* in *H-plane*, with and without the central shorting pin for *Duroid 5880*. HPBW in *H-plane* which can be determined from this figure as $\theta_{BH}= 69.3°$. *Fig 8*a,b shows that in *E-plane*, with and without the central shorting pin for *Duroid 5880*. HPBW in *E-plane* is $\theta_{BE}= 51.9°$. Fig. 9 a,b shows the correspond normalized radiated power pattern in polar and rectangular plots. It is clear, from these plots that the central shorting pin, offers a small degrading in the far field radiation pattern, and gives a considerable effects on bandwidth as seen in Fig. 6 .

b) Consider the proposed modified shape microstrip antenna *(MSMSA)* which gives improvement in the radiation characteristics and bandwidth over *RMSA*.

This *MSMSA* is also simulated and tested using microwave office package, with and without central shorting pin, for the two substrate materials the *Duroid 5880* and *Quartz*.

Fig. 10 shows the *VSWR* variation with respect to frequency for the modified shape patch with and without central shorting pin, for *Duroid 5880* and *Quartz* . *VSWR BW≤2* of *Duroid 5880* without central shorting pin is *2.54 GHz (25.4%)*, whereas with central shorting pin is *2.62 GHz (26.2%)*, while for *Quartz* is enhanced from *2.39 GHz (23.9%)*, to *3.09 GHz (30.9%)by using central shorting pin*.

Fig. 11a,b shows the electric field in polar and rectangular plot, of the *Duroid 5880 (MSMSA)* in *H-plane*, with and without the central shorting pin. HPBW are $\theta_{BH}= 57.4°$ and $\theta_{BH}= 59.6°$ respectively for the two cases. Fig. 12 a,b shows the Electric field plots in E-plane where $\theta_{BE}= 15.86°$ for the two cases.

Fig. 13 a,b shows the normalized radiated power pattern for MSMSA in polar and rectangular plots, with and without the central shorting pin for *Duroid 5880* .

It is clear that the central shorting pin, gives a considerable effect on bandwidth of MSA.

6. Conclusion

One of the main problems arises with the operation of MSA is the surface wave excitation. Reduction of surface wave is done by adjusting the substrate height with respect to the dielectric constant substrate material.

The selection of substrate materials used in this design processes is based on two materials, *Duroid 5880* and, *Quartiz.*

Broadening the bandwidth of the rectangular microstrip antenna was achieved by using a method of *lowering quality factor*, *shift feeding point position*, *reactive loading* and by *modification of the patch shape.* For substrate material *Duroid 5880*, initial with *9.7%* bandwidth with low quality factor *RMSA* fed at original feeding point getting as overall of *26.2%* bandwidth with modification in patch shape where reactive loading was used. While for *Quartz*, initial with *15.5%* a percentage to be enhanced to *30.9%* by using shape modification and, insertion of central shorting pin. Table 3 shows the enhancement in BW% for the proposed types of MSA .

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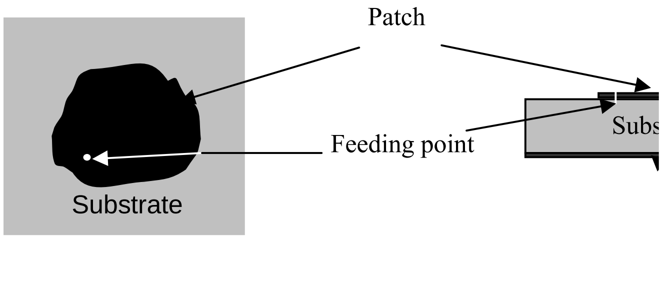


Top View Side View

Fig. 1 Arrangement of arbitrary shaped microstrip antenna (MSA)

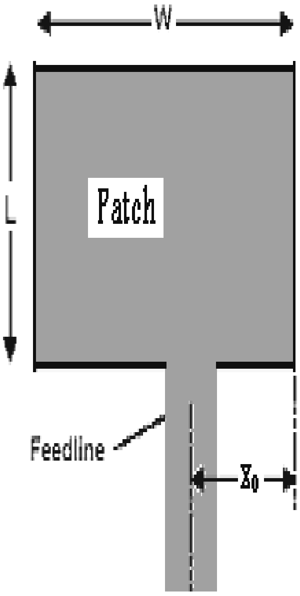
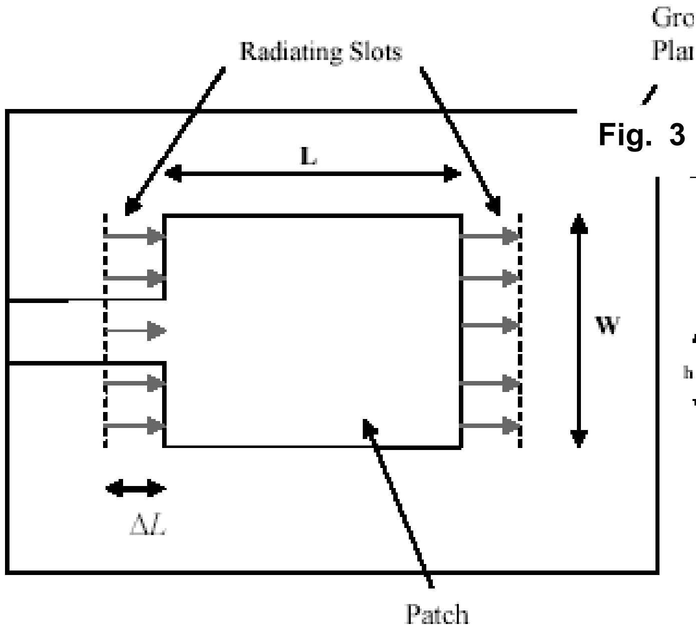
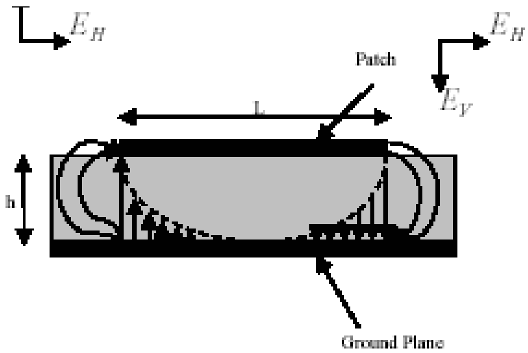


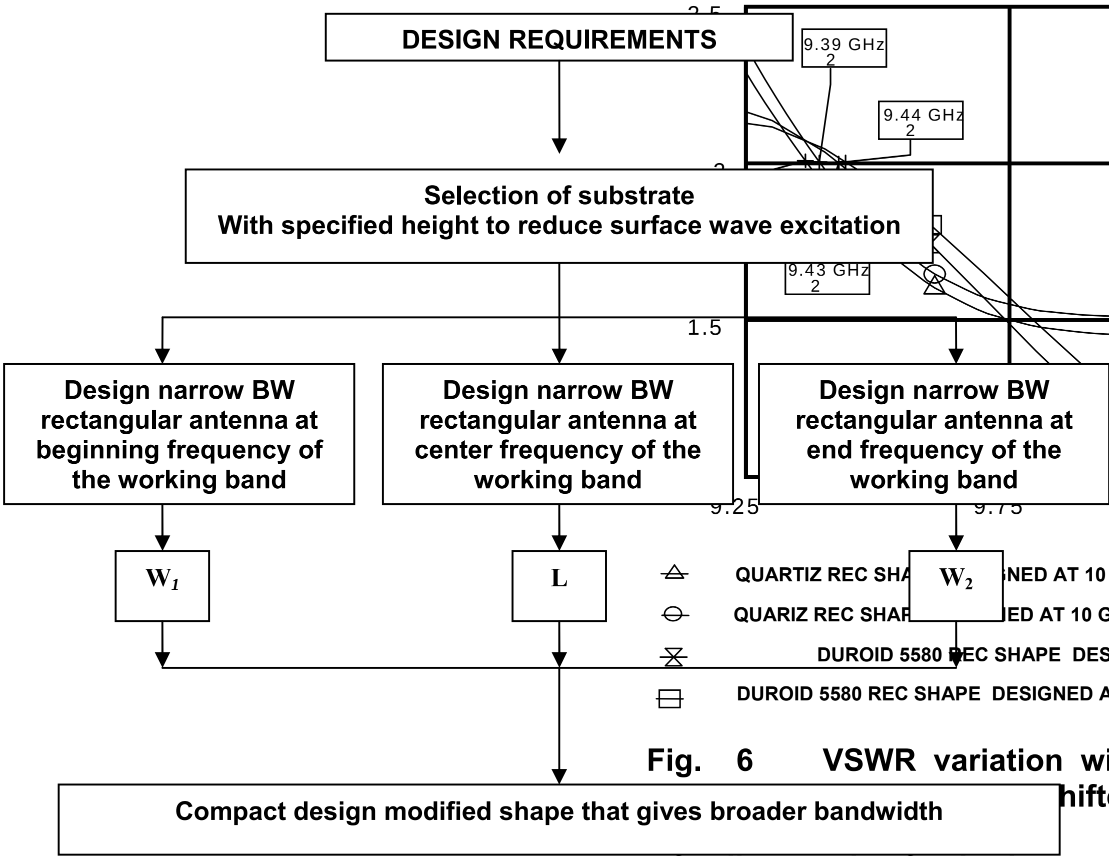
Fig. 3 Feed positions on patch





(a) Top view
(b) Side view

Fig. 2 Top and side views of rectangular microstrip antenna (RMSA) with two Slots.



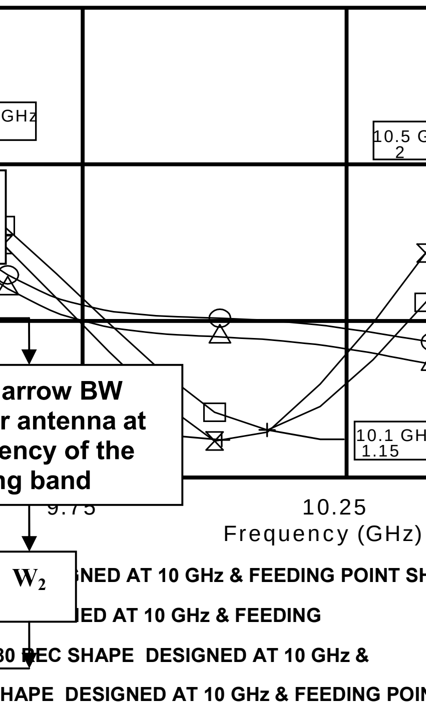


Fig. 6 VSWR variation with hifted

feeding point for both cases with and without central shorting pin and for substrate materials Duroid 5880 and Quartiz.

Fig. 4 Flow Chart of the Main Design Process

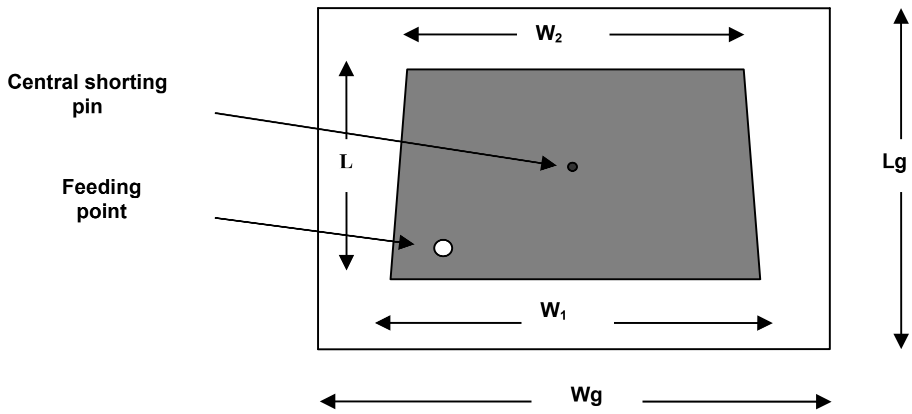
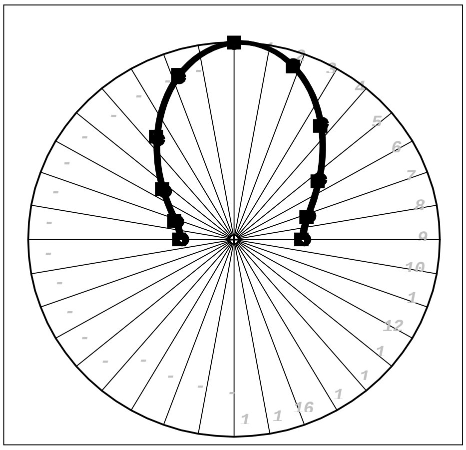


Fig. 5 Modified Shape Microstrip Antenna.



(a)

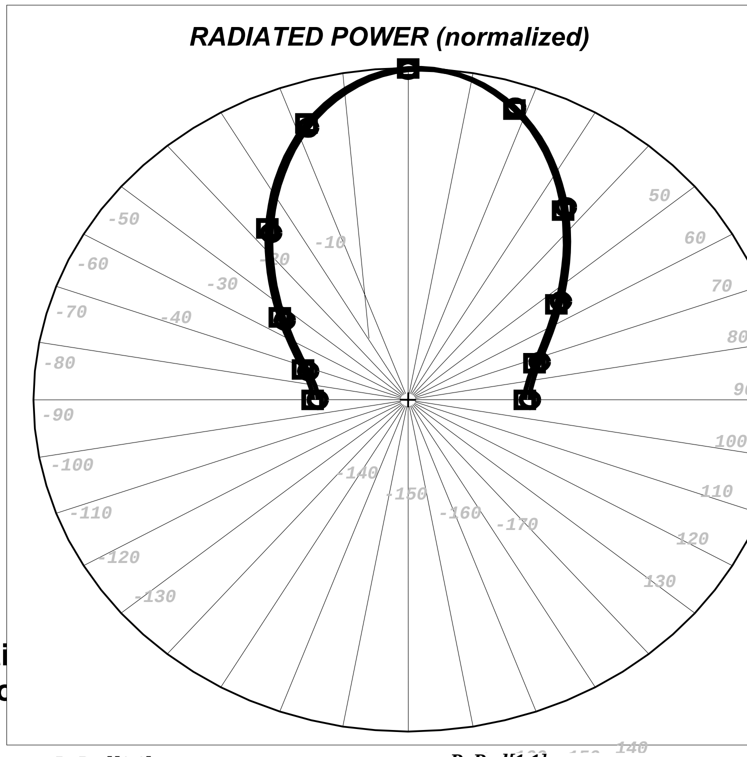
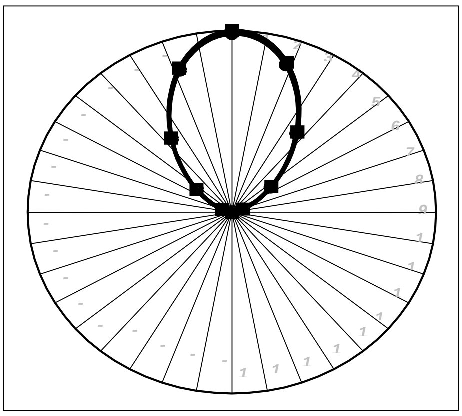
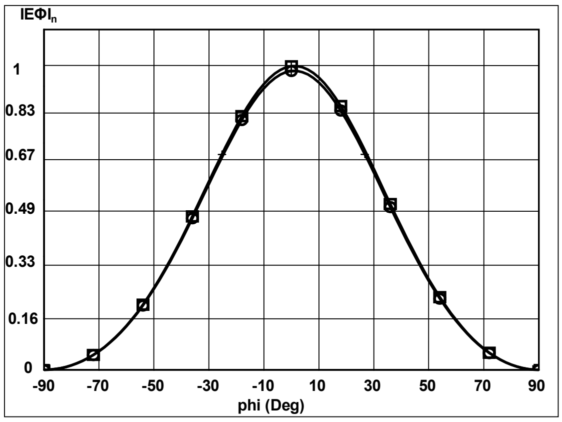


Fig. 7 ***H-plane*** **electric field radiati cases with and without central sho** ***Duroid 5880*** **(a) normalized polar plot**

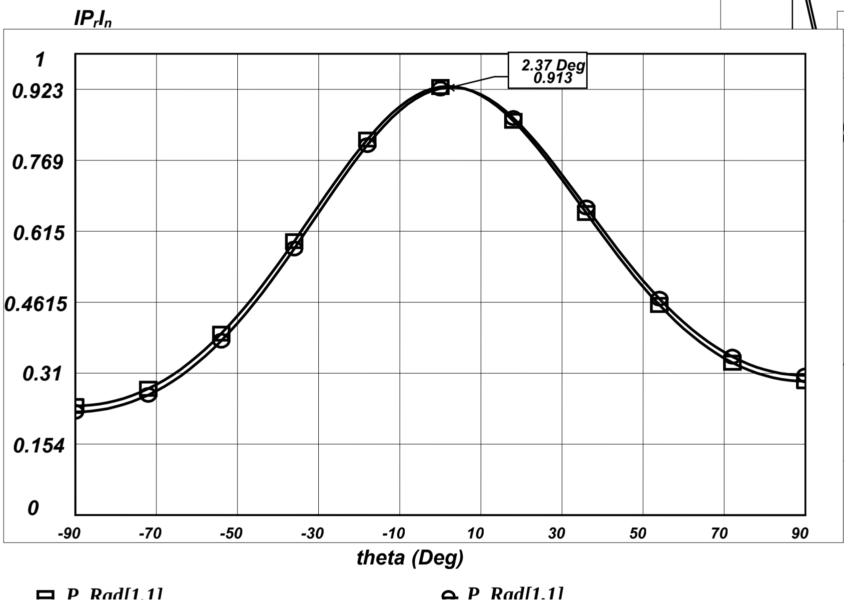


(a)



(b)

Fig. 8 ***E-plane***, ***E=f(Φ)*** **for RMSA for both cases with and without central shorting pin and for substrate material** ***Duroid 5880*** **(a)normalized polar plot, (b) normalized rectangular plot.**



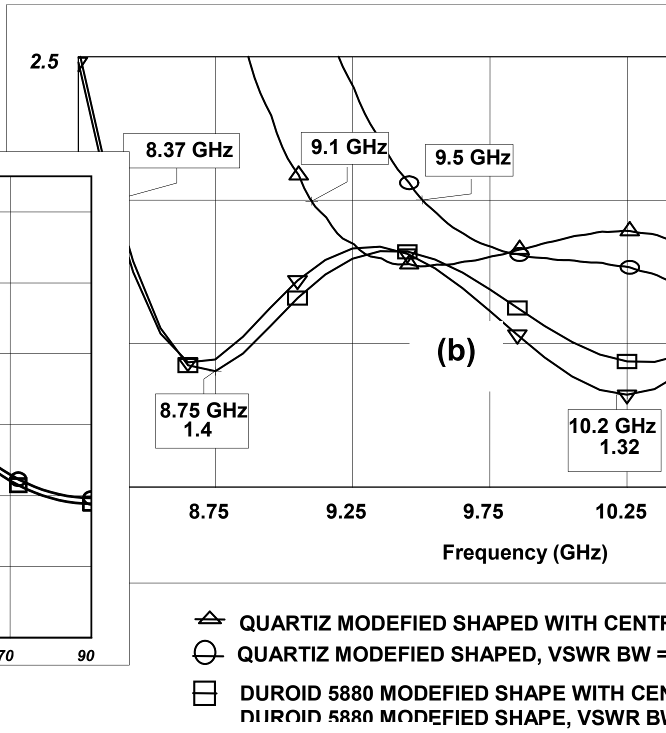


Fig. 9 ***Radiated power*** **pattern for RMSA for both cases with and without central shorting pin and for** ***Duroid 5880*** **(a) polar plot. (b) rectangular plot.**

equency for mod and without central shorting pin for substrate ma

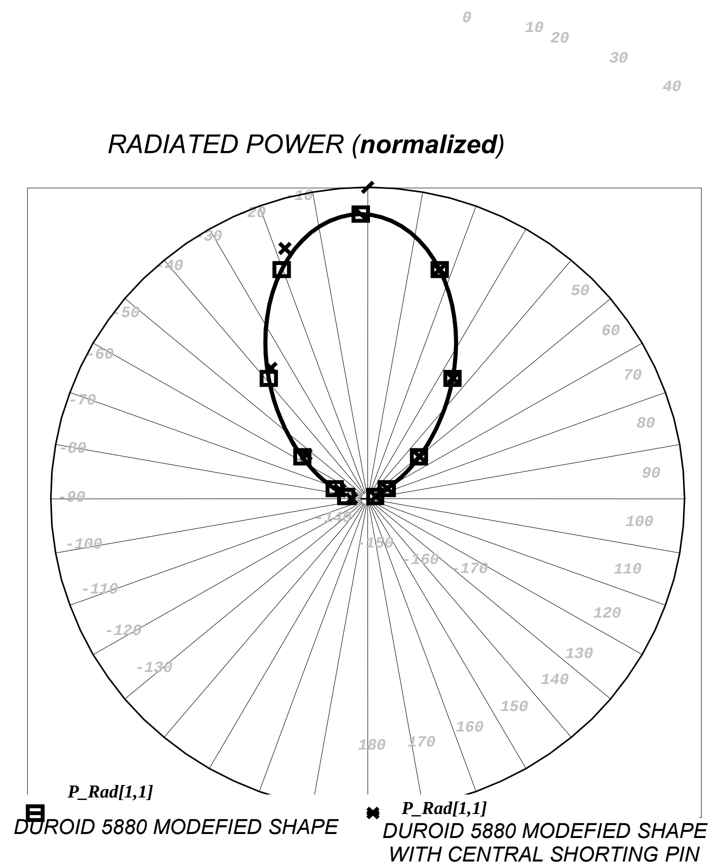
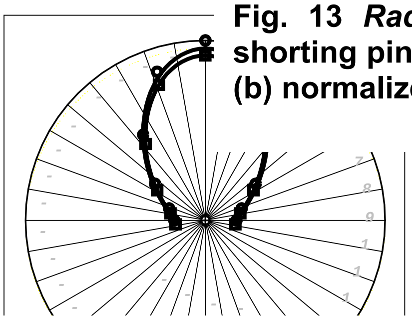
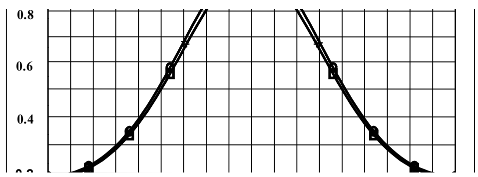


Fig. 13 ***Radiated power*** **pattern for MSMSA with and without central shorting pin with substrate material** ***Duroid 5880*****. (a) normalized polar plot. (b) normalized rectangular plot.**





material	ε_r	h cm	L cm	W_1 cm	W_2 cm	X_f cm	Y_f cm	L_g cm	W_g cm
Air	1	0.17	1.268	1.875	1.25	0.9375	0.6340	2.288	2.895
Duroid 5880	2.2	0.17	0.8976	1.48232	0.988212	0.74116	0.3200	1.9176	2.50232
Duroid 5870	2.33	0.17	0.8735	1.4531	0.96873	0.72655	0.304	1.8935	2.4731
Quartiz	3.78	0.17	0.6885	1.213	0.809	0.6065	0.24	1.7085	2.233
Duroid6006	6.15	0.057	0.592	0.992	0.6611	0.496	0.127	0.934	1.334
Alumina	9.8	0.057	0.46764	0.8069	0.538	0.40345	0.0804	0.80964	1.1489
Silicon	11.9	0.057	0.4234	0.7383	0.4922	0.36915	0.066413	0.7654	1.0803
Gallium Arsenide	12.9	0.057	0.4061	0.71123	0.4742	0.355615	0.06133	0.7481	1.05323

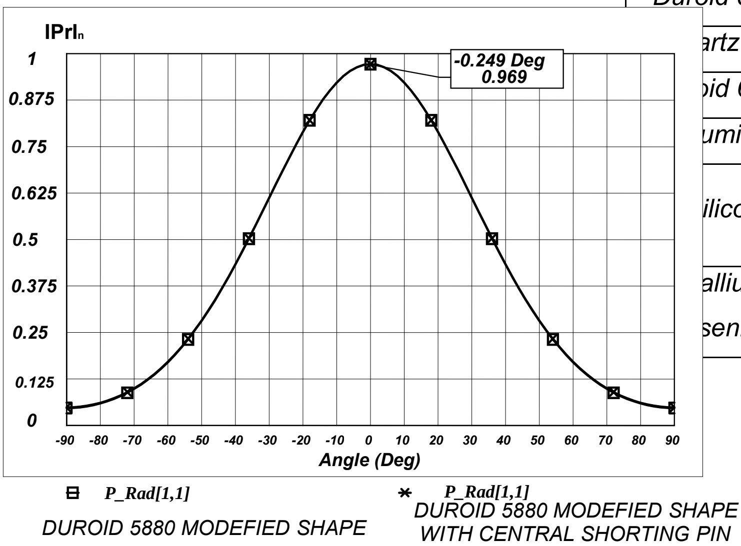


Table 2 Calculated dimensions for different materials

Table 1 Results calculated for various substrate materials at 10 GHz for rectangular microstrip antenna.

Table 3 Percentage bandwidth of various types of MSA.

Substrate	ε_r	h cm	W cm	ε_{reff}	ΔL cm	L cm	L_g cm	W_g cm	%BW	D dB
Duroid 5880	2.2	0.17	1.1859	1.9638	0.0864	0.8				
Duroid 5870	2.33	0.17	1.1625	2.0657	0.0851	0.8				
artz	3.78	0.17	0.9703	3.1792	0.0764	0.6				
oid 6006	6.15	0.057	0.79333	5.462	0.025	0.				
umina	9.8	0.057	0.6455	8.466	0.02395	0.4				
ilicon	11.9	0.057	0.591	10.161	0.0236	0.4				
allium senide	12.9	0.057	0.569	10.96	0.0235	0.4				

Substrate material / Antenna type	*Duroid 5880*	*Quartiz*
Rectangular patch fed at original point	9.7% BW	15.5% BW
Rectangular patch shifted feeding point	10.8% BW	16.1% BW
Rectangular patch shifted feeding point with central shorting pin	11.6% BW	17.4% BW
Modified patch shape	25.4% BW	23.9% BW
Modified patch shape with central shorting pin	26.2% BW	30.9% BW