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COUPLING METHODS OF DIELECTRIC RESONATOR ANTENNA

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ABSTRACT

The paper briefly reviews the various coupling methods to excite Dielectric Resonator Antenna (DRA). Various coupling methods such as coaxial probe feed, micro strip feed, coplanar feed, aperture coupling and dielectric image guide are discussed including their advantages and disadvantages. Coaxial probe feed and micro strip feed are initially used to excite the DRA but the unwanted radiation from the feed causes the distortion and degrades the radiation pattern. Aperture coupling method is investigated and become most popular in which the feed is located beneath the ground to avoid spurious radiations. Also quarter wavelength stub length in aperture coupling can improve the coupling to the DRA as its reactance cancels out to that of the slot and enhances the matching. It is also observed that to design circular polarized DRA, dual ports excitation is preferred over single port so as to yield a wider 3dB Axial Ratio (AR) bandwidth.

KEYWORDS: *Dielectric resonator antenna, Excitation techniques, Aperture coupling, Microstip feed, Dielectric feed.*

1. INTRODUCTION

DRA is useful for broadband and higher microwave applications hence it is always attraction for research and investigation [1].Theoretical and experimental investigations have been reported by many investigators on various excitation techniques of the DRA [2-3]. Brief study and analysis of each excitation techniques is carried out to give the overview on how to choose the appropriate coupling method while designing the DRA.

2. LITERATURE REVIEW OF COUPLING METHODS

Dielectric resonator with proper excitation, act as dielectric resonator antenna. To couple the energy to the DRA typical electric or magnetic source is to be considered. Resonance of the DRA is function of the position of the feed with respect to DRA. Normally feed should be placed in the stronger electric or magnetic field [4].
Let if J_1 is the source electric current and E_2 is the Electric field inside the DRA then the amount of coupling from electric source is given by:

$$k \propto \int (\overrightarrow{E_2}.\overrightarrow{J_1})dV \dots\dots\dots\dots\dots\dots (2.1)$$

Similarly if M_1 is the magnetic current source and H_2 is the magnetic field inside the DRA

Then the amount of coupling from magnetic source is given by:

$$k \propto \int (\overrightarrow{H_2}.\overrightarrow{M_1})dV \dots \dots \dots (2.2)$$

The coupling mechanism transfers the energy to the DRA and also shows the loading effect which controls Q factor of the DRA.

Both external Q- factor and loaded Q-factor are expressed mathematically

$$Q_L = \frac{Q}{k} \dots \dots \dots \dots \dots \dots .. (2.3)$$

$$Q_L = \frac{Q}{1+k} \dots \dots \dots \dots . \dots \dots (2.4)$$

Where Q is the unloaded Q and k is the coupling factor.

Maximum power is transferred from the coupling port to the DRA when k =1 so in view of it a particular excitation method is selected.

DRA can be fed by a variety of methods. These methods can be classified into two categories: contacting and non-contacting. In the contacting method, the RF power is fed directly to the DRA using a connecting element such as a micro strip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the micro-strip line and the DRA.

Following are the main excitation techniques of DRA.

2.1 PROBE COUPLING

Probe coupling was used firstly used by S.A.long in 1983 followed by other researchers G.P. Junker, A.A. Kisk and others to study the DRA due to its advantage of strong coupling. The Probe coupling is mainly used to couple the DRA at low frequency where the aperture coupling is not feasible due to large slot size [4-5]. Probe coupling to the rectangular DRA is depicted in Figure 1. The field lines associate with DRA due to inserted probe coupling and external probe coupling is shown in the Figure 1.

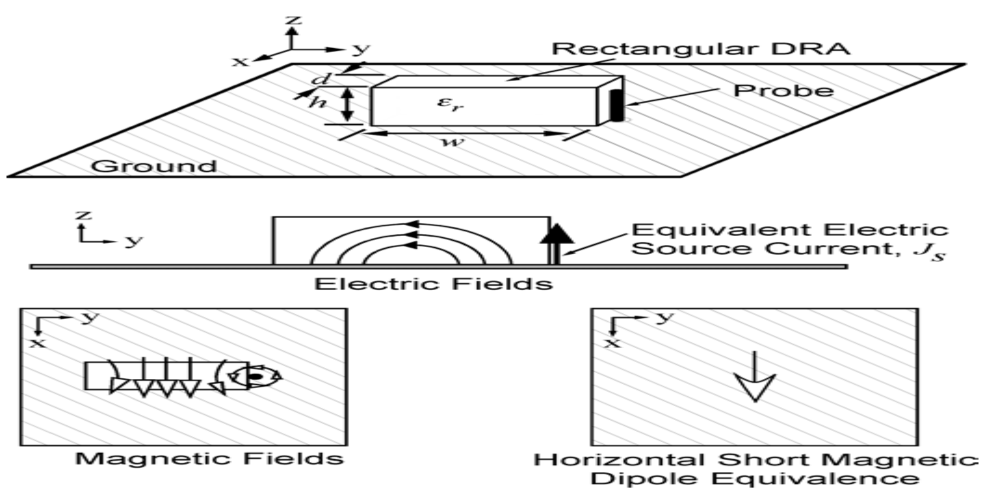


Fig. 1 Probe Coupling to Rectangular DRA

The main advantage of this feeding scheme is that the feed can be placed at any desired location inside the DRA in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation [6-7]. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model as a hole required to be drilled in the substrate and DRA. The increased probe length makes the input impedance more inductive, leading to matching problems [8-9]. If the probe is located adjacent to the DRA, the $TE_{\delta 11}$ mode will be excited in a rectangular DRA, the $HE_{11\delta}$ and the $TE_{01\delta}$ will be excited in the cylindrical and half cylindrical DRA respectively. To excite the $TM_{01\delta}$ mode in the cylindrical or ring DRAs, the probe must be in the centre of the DRA [10-11].

2.2 MICROSTRIP LINE COUPLING

Microstrip coupling is presented by R.A.Kranenburg& S.A. Long in 1988, Myung Ki Kim, A. Petosa, Bin Li, K. W. Leungand many others highlighted this coupling mechanism with different DRA geometry. It has advantage over probe coupling of being simple and planar that maintains the DRA size small. Microstrip line coupling to rectangular DRA and cylindrical DRA along with induced fields is given in Figure 2. [12-16].

The $TE_{\delta 11}$ and $HE_{11\delta}$ modes could be excited by the microstrip line feeding technique in the rectangular and cylindrical DRAs respectively. The microstrip line could be extended underneath the DRA by a small space (Δl) for a direct coupling or adjacent to the DRA by a space (Δs).The amount of coupling is a function of space (Δl) and distance between feed & DRA (Δs). The main disadvantage of this coupling scheme is the spurious radiation due to the microstrip line that exhibits in stable radiation patterns and low polarization purity [17-18].

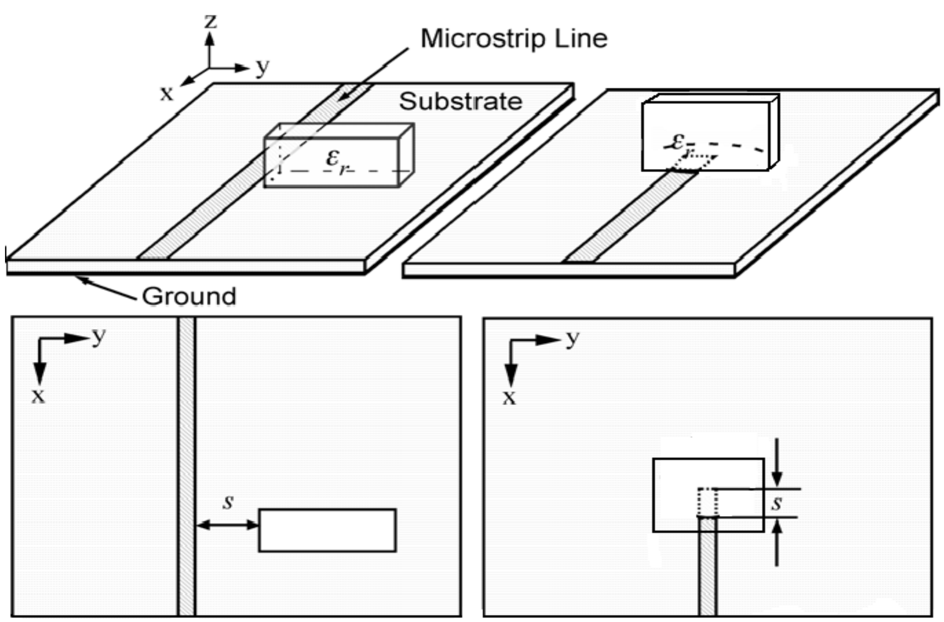


Fig. 2(i): Microstrip Line Coupling

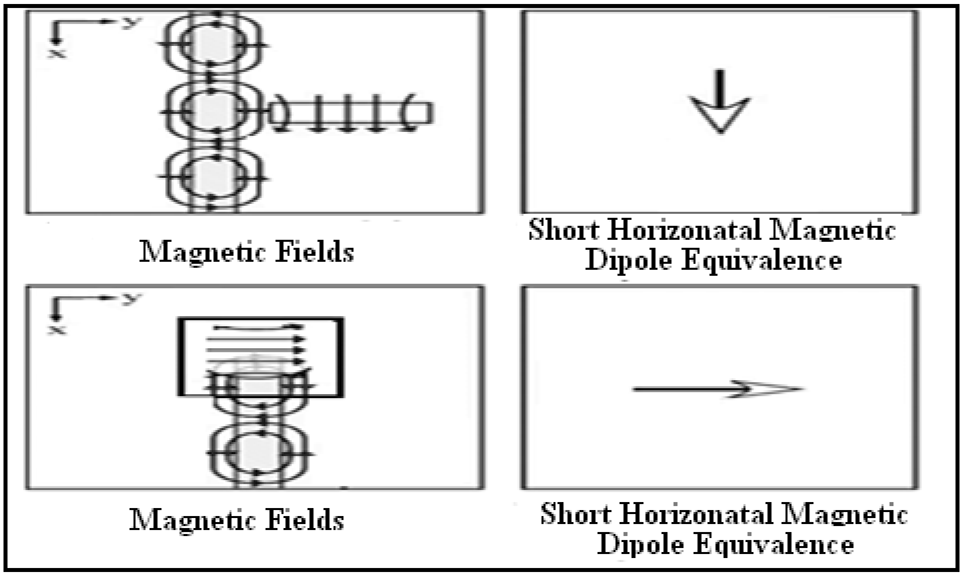


Fig. 2(ii) Induced Field due to Micro strip Line Coupling in Rectangular DRA

2.3 COPLANAR FEEDS

The coplanar feed is another coupling method to transfer the energy to the DRA. Recently Y. Gao and Z. Feng in 2011 proposed coplanar waveguide DRA with compact design. Analysis and application of coplanar wave guide fed DRA were also investigated by many researchers: M.S.AlSalamehinin 2002, Y.M. Antar, S.Deng and X.Q. Sheng in 2004, M. B. Ghosh in 2005 [19-23].Various coplanar feeds and coupling to DRA are illustrated in Figure 3.

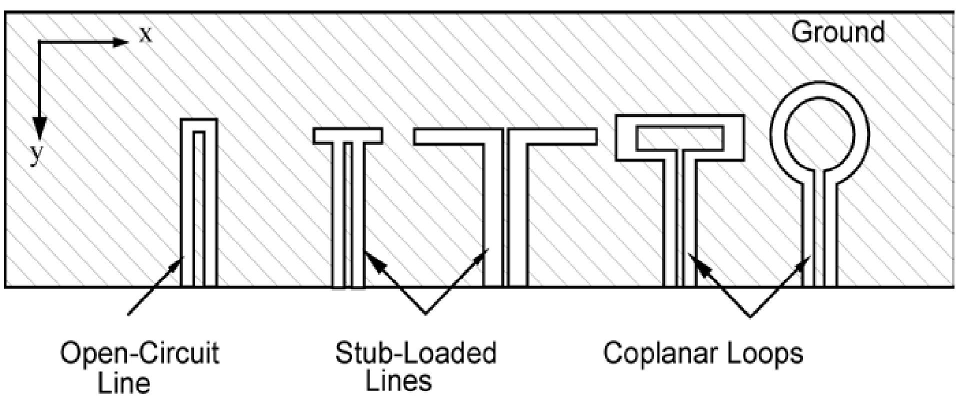
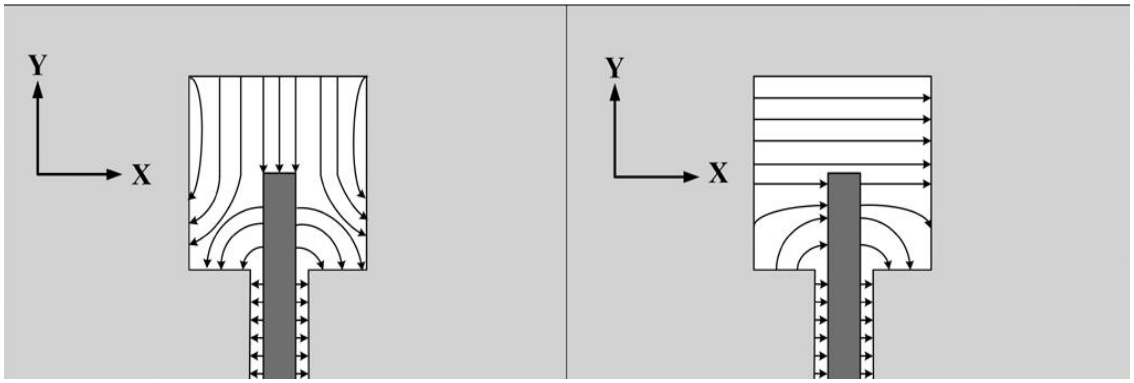


Fig. 3 Various Coplanar Feeds for Excitation of DRA

Field configuration due to coplanar coupling to rectangular DRA for even and mode is given in Figure 4. The amount of coupling and particular mode excitation can be obtained by slightly moving the DR element over the feed. In the coplanar coupling method, desired resonance frequency and radiation patterns can be obtained by moving the DRA from the edge to the centre on the loop. The coplanar feed dimensions should be large enough for adequate amount of coupling but small enough to avoid a large back lobe level. The coplanar stub loaded lines or coplanar loops are used for controlling the impedance matching of the DRA.



(i) **(ii)**

Fig. 4 Electric Field Distributions in CPW Fed DRA (i) Odd Mode (ii) Even Mode

2.4 APERTURE COUPLING

Various feed methods as coaxial probe feed, microstrip feed methods are already available but the unwantedradiation from the feed causes the distortion and degrade the radiation pattern. Thus the aperture coupling method is most popularin which the feed is located beneath the ground to avoid spurious radiations.G.P. Junker in 1994 and Y.M. Antar& Z. Fan in 1996 has carried the theoretical investigation of aperture coupled rectangular DRA. A. Buerklein 2005 and many other researchers presented the aperture coupled DRA designs to exploit its advantages. Another advantage is that quarter wavelength stub length can improve the coupling to the DRA as itsreactance cancels out to that of the slot and enhances the matching. The DRA placed on the center of the aperture acts like a magnetic current flowing along the slot length and as a result it behaves like a magnetic dipole. The slot is fed by microstrip line because it is easy to etch on the substrate and to achieve impedance matching. Slot's dimensions are kept small enough to avoid backward radiation and large enough to couple sufficient amount of energy. Various apertures (slot) like rectangular, cross, circular, C, etc. are shown inFigure 5.Also resonance of slot can be utilized to enhance the bandwidth of DRA [24-30].

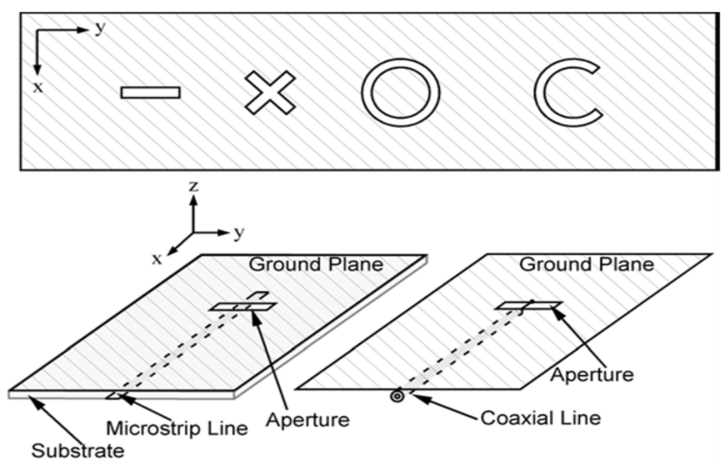


Fig. 5 Various Slot Apertures for Coupling to DRAs

The small rectangular slot is probably the most widely used aperture [31- 33].Annular slots have also been used for exciting cylindrical DRAs, while cross shaped and C-shaped slots are used to excite circular polarization. The aperture coupled rectangular DRA and the induced fields are depicted in Figure 6.

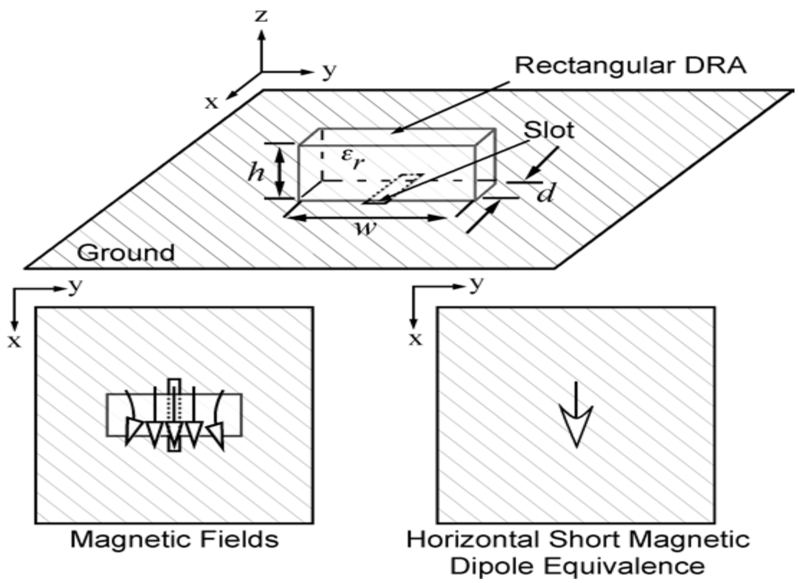


Fig. 6 Apertures Coupling to a Rectangular DRA

2.5 DIELECTRIC IMAGE GUIDE

In 1981M.T Birand and R.V. Gelsthorpe carried out the experimentation on dielectric image guide fed DRA at millimeter frequency. Also M.Wyville, A. Petosa, and J.S. Wight in 2005 and many others used the dielectric image guide feed for DRA Array. At millimetre-wave frequencies, the conductor losses offered by microstrip feed lines become significantly high. To avoid this problem the use of dielectric image guide is preferred.Figure (5) shows the dielectric image fed DRA. It is equivalent to a short horizontal magnetic dipole. The dielectric image guide couples the energy to the DRA that is located in its proximity and coupling level can be improved by choosing higher permittivity. This method also offers an advantage that it can be used as series feed to linear array designs [34-35].

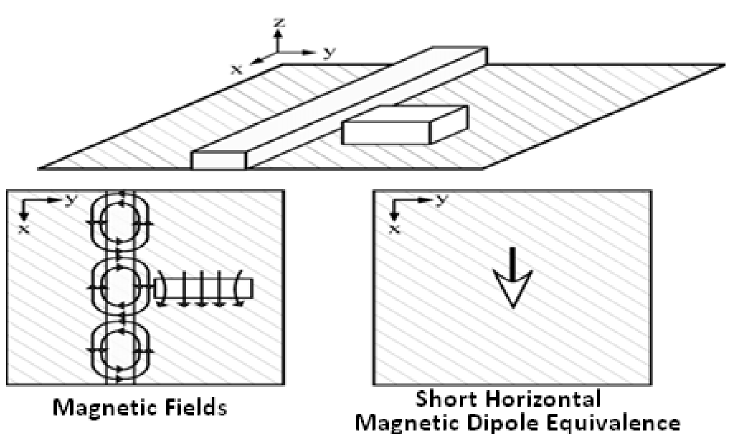


Fig. 7 Dielectric Image Guide Feed for DRAs

2.6 DUAL PORT EXCITATIONS

To obtain circular polarized DRA, dual ports excitation is preferred over single port so as to yield a wider 3dB Axial Ratio (AR) bandwidth. For both circular and linear polarizations, highly decoupled ports are usually required. Dual port excitation is widely used for obtaining both dual polarization and circular polarization [36-39].

3. CONCLUSION

Different coupling methods for the excitation of DRA are studied. It is observed that various feed methods are used for different applications and have their own merits. The coplanar stub loaded lines or coplanar loops are used for controlling the impedance matching of the DRA.The dielectric image guide couples the energy to the DRA that is located in its proximity and coupling level can be improved by choosing higher permittivity. This method also offers an advantage that it can be used as series feed to linear array designs. It is concluded thatthe aperture coupling to DRA is preferred in many applications because it has advantage of having feed network below ground plane, avoiding spurious radiation.It is easy to design by simply etching the slot on ground plane. Slot can also be used as a resonant structure in addition to coupling to DRAs. The extended feed line beyond the slot called stub cancels out the reactive component of the slot.

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