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Theoretical analysis of short backfire antenna by using Moment of method

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ABSTRACT

The short backfire antenna is one of the important types of antennas due to its high directional and other characteristics. Therefore, this research deals with, a theoretical study to calculate the radiative structures of a short backfire antenna as an axially symmetric body using the moment method.

The main goal is to theoretically calculate the radiation fields and compare them with previous practical researches. Where the mathematical analysis with the used software was verified by comparing the results and noting the extent of the match.

The other goal is to study the effect of the antenna dimensions on its performance by studying the effect of adding a rim to the edge of the large back reflector, as well as studying the change of the radius of the two reflectors (large and small), where it was confirmed that the best value for the radius of the large reflectors and small (R_m=1λ) (R_s= 0.25 λ) respectively.

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التحليل النظري لهوائي عكسي قصير باستخدام طريقة العزوم

علي كريم نعمة **زكي عبد الله احمد** **وائل عبد اللطيف كديمي**

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الــــخُـــلاصـــة

يعد الهوائي العكسي القصير أحد أنواع الهوائيات المهمة نظرًا لخصائصه عالية الاتجاه وغيرها من الخصائص. لذلك، يتناول بحثنا هذا، دراسة نظرية لحساب الهياكل الإشعاعية لهوائي عكسي قصير كجسم متناظر محوريًا باستخدام طريقة العزوم.

الهدف الرئيسي هو حساب المجالات الإشعاعية نظريًا ومقارنتها بالأبحاث العملية السابقة. حيث تم التحقق من التحليل الرياضي مع البرنامج المستخدم بمقارنة النتائج مع ملاحظة مدى التطابق.

الكلمات المفتاحية:

الهوائي العكسي القصير
طريقة العزوم
الهياكل الاشعاعية
الاجسام المتناظرة محوريا

الهدف الآخر هو دراسة تأثير أبعاد الهوائي على أدائه من خلال دراسة تأثير إضافة الحاشية إلى حافة العاكس الخلفي الكبير، وكذلك دراسة تغير نصف قطر العاكسين (الكبير والصغير) حيث تم التأكد من أن أفضل قيمة لنصف قطر العاكسات الكبيرة والصغيرة $(R_m=1\lambda)$ $(R_s= 0.25\ \lambda)$على التوالي.

1. INTRODUCTION

Antennas are beneficial mode of communication in distinctive fields; antennas are used to talk in shape of audio, video, graphically. As their significance in conversation antennas are strengthen time to time in accordance to the need. Antennas are design for different application of different materials, structures for better communication. They are design for radio, television, satellite, broadcasting, and cell gadget etc., communications. [1]

Rapid increase in mobile communication structures requires use of low profile, light weight, simple diagram and low cost antennas in order to get environment friendly results. Those structures that transmit antennas in their free space can tie-up mobility, accessibility and can have enough vary without amplification [2]

Reflector antennas have been used for about fifty years in radio astronomy microwave communication and remote sensing. The backfire principle is an effective technique for improving the radiation characteristic of an antenna without increasing its physical length.

A short backfire antenna is a kind of a directional antenna, characterized by using high gain, Relatively small size, and (narrow) band. The short backfire antenna was first conceived through Ehrenspeck in1960s, SBF antenna has received a lot pastime for its recommended characteristics such as compactness, simplicity of construction, high obtain and so on. The traditional Short backfire antenna consists of two parallel plate reflectors with distinct dimensions (a large and small reflectors), spaced a distance about λ/2 apart. SBFAs are used in some satellites and in high-frequency (short-wavelength) conversation tools (often for conversation with satellites) on ships and different applications where rugged development is an advantage. They are additionally used for Wireless Local Area Networks (WLANS). The backfire antenna operates in a resonant mode. This means that no easy theories are handy to predict the performance, and most of the posted statistics concerned with the quick backfire antenna reviews experimental records due to the difficulty of theoretically modeling the antenna [3]

This type of antennas usually consists of two small reflectors (R1), a large reflector (R2) and a rim surrounding the back reflector. As shown in Figure 1. The radii of the reflectors are different, separated by a certain distance, and on the basis of which the type of reflector is determined, it may be of the type (long backfire antenna) if the distance between the two reflectors is large or the distance may be less than that of the type used in the search (short backfire antenna), And the location the feed between the two reflectors, separated by a distance (0.5 λ), where (λ) is the wavelength from the free space. Type of feed is either a dipole, a waveguide or other types. Addition The edge ,it height is 0.25λ, leds to the gain increases by about 1 dB [4]

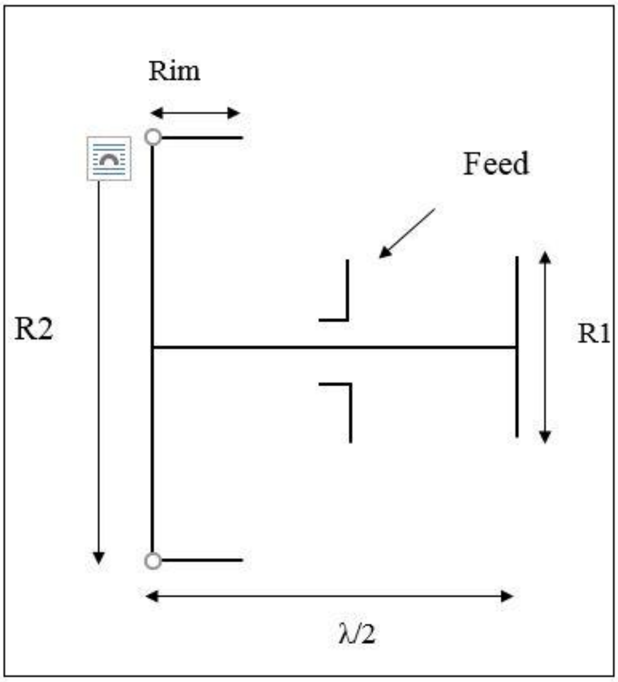


FIG 1. The proposed Short Backfire Antenna.

Table (1-1) The electrical dimensions of the antenna SBFA

Distance between two reflectors	L=0.5λ
Radius of diameter to front reflector	R_m=1.0λ
Radius of diameter to back reflector	R_s=0.2λ
Width Rim	W_{rim}=0.25λ
Frequency	Freq.=3GHz

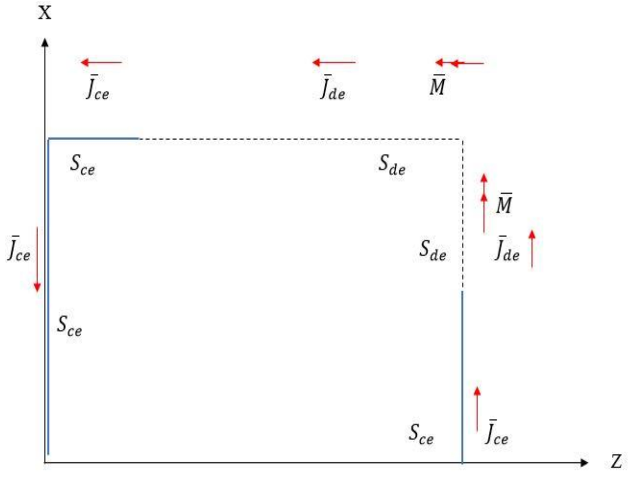
Over the year's various forms of antenna types have been used, and many have been investigated improvements by experimenting with different shapes and sizes of reflectors or adding a Rim for a back reflector.

Analysis and Calculations

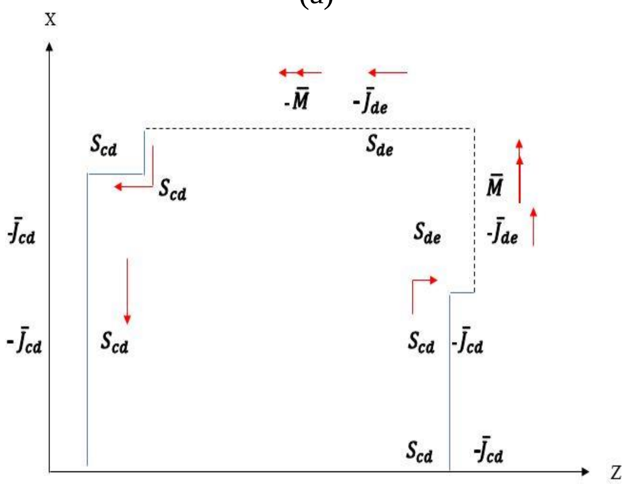
Antennas and their sketch techniques are among the most necessary purposes that are used in our life, as they generally based on electromagnetic theory. To resolve any electromagnetic issue is theoretically represented, the usage of a one of the analytical and numerical models. Among the analytical way used, the primary focus of this lookup on MoM, due to its wide features, specially the purposes using the body of revolution (BoR). This type of antenna has a number of applications, and the most essential of which is in the military applications "such as missiles". [5][6]

There are two options to obtain the unknown surface electric and magnetic currents which are numerical solutions and different options (analytical), Since analytical solutions are now not used for arbitrary objects, we used the numerical method. The radiation problem for axially symmetric bodies is formulated using the integral equation of the electric field EFIE, which is solved by the method of moment. Through the electric and magnetic currents, the radial structures of the field can be calculated. The numerical integration technique is often used to gain the outcomes due to the fact the quality of the consequences got from the torque method depends on the accuracy of the matrix factors [7]

To discover(obtain) the radiation pattern issued (flowed from)via a short backfire antenna, the (principle) of equivalence is applied, which divides the antenna into an exterior valence area $[V^e]$ that consists of the surface S_{ce} (a surface separates the conductor with free space) and the surface S_{de} (a surface separates the conductor and insulator)[8], see Figure2(a). whereas, Figure.2(b) indicates of the inner valence area $[V^d]$ that includes the surface S_{de} and the surface S_{cd} (surface separates both of the conductor and insulator).



(a)



(b)

FIG. 2. shown the segment an object for Two region ((a)exterior and (b)inner valence area)

Using the equivalence principle that change the sources of the magnetic field with equivalent sources, surface currents can be written as form [9]:

$$\bar{J}s=\hat{n}\times\bar{H}s \quad (1)$$

$$\bar{M}s=-\hat{n}\times\bar{E}s \quad (2)$$

The backfire antenna is made of conductive and insulating materials, so there are two conditions on the dielectric and conductive materials. These conditions make the electric field compounds tangent to the surface of the conductor gradually disappear, and the magnetic field and electric field are continuous on the surface of the insulator. [10]. Described as follows:

$\hat{n}\times\bar{E}^{e}=0$ on S_{ce} (3a)

$\hat{n}\times\bar{E}^{d}=0$ on S_{cd} (3b)

$\hat{n}\times\bar{E}^{d}=\hat{n}\times\bar{E}^{e}$ on S_{de} (3c)

$\hat{n}\times\bar{H}^{d}=\hat{n}\times\bar{H}^{e}$ on S_{de} (3d)

From these conditions, the density of surface currents can be obtained:

$\bar{J}_{ce}=\hat{n}\times\bar{H}^{e}$ on S_{ce} (4a)

$\bar{J}_{cd}=\hat{n}\times\bar{H}^{d}$ on S_{cd} (4b)

$\bar{J}_{de}=\hat{n}\times\bar{H}^{e}$ on S_{de} (4c)

$\bar{M}=-\hat{n}\times\bar{E}^{e}$ on S_{de} (4d)

The electric current J is generated on the conducting and insulating surfaces, while the magnetic current is generated on the insulating surface only. Therefore, when applying the equivalence principle to the external and internal equivalence regions of the problem, the integral equations can be written as follows: -

$$\hat{n}\times\bar{E}^{e}(\bar{J}_{ce}+\bar{J}_{de},\bar{M})=0 \quad on\ S_{ce} \quad (5a)$$

$$\hat{n}\times\bar{H}^{e}(\bar{J}_{ce}+\bar{J}_{de},\bar{M})=0 \quad on\ S_{de} \quad (5b)$$

$$\hat{n}\times\bar{E}^{d}(-\bar{J}_{cd}-\bar{J}_{de},-\bar{M})+\hat{n}\times\bar{E}^{d}(\bar{J}^{id},0)=0 \quad on\ S_{cd} \quad (5c)$$

$$\hat{n}\times\bar{H}^{d}(-\bar{J}_{cd}-\bar{J}_{de},-\bar{M})+\hat{n}\times\bar{H}^{d}(\bar{J}^{id},0)=0 \quad on\ S_{de} \quad (5d)$$

Where $\bar{E}^{d}(\bar{J}^{id},0)$ and $\bar{H}^{d}(\bar{J}^{id},0)$ represent the electric and magnetic fields respectively generated as a result of the induced electric current J and the induced magnetic current M which in turn radiates into the region described by the coefficients $(\mu_a \text{‘} \varepsilon_a)$ the sample (a) denotes the valence region e or d, Either $\bar{E}^{e}(\bar{J},\bar{M})$, $\bar{H}^{e}(\bar{J},\bar{M})$, $\bar{E}^{d}(\bar{J},\bar{M})$, $\bar{H}^{d}(\bar{J},\bar{M})$ denotes to the electric and magnetic fields, resulting from the equal currents $\bar{J}$and $\bar{M}$.

The unknown quantities (equivalent surface currents) can be written as a function of the set of test functions using the trigonometric functions and the Fourier series, as:

$$\bar{J}(\bar{r})=\bar{J}^{\bar{t}}(t\text{‘}\emptyset)+\bar{J}^{\bar{\emptyset}}(t\text{‘}\emptyset)=\sum_{n=-\infty}^{\infty}\left[\bar{J}_{n}^{t}(t)+\bar{J}_{n}^{\emptyset}(t)\right]e^{jn\emptyset} \quad (6)$$

$$\bar{M}(\bar{r})=\eta_a\left(\bar{M}^{t}(t\text{‘}\emptyset)+\bar{M}^{\emptyset}(t\emptyset\text{‘})\right)=\sum_{n=-\infty}^{\infty}[\bar{M}_{n}^{t}(t)+\bar{M}_{n}^{\emptyset}(t)]e^{jn\emptyset}\ \eta_a \quad (7)$$

Whereas η_a is impedance vacuum

From the above equation we obtain: -

$$(\bar{J}_{ce}+\bar{J}_{de})=\sum_{n=-\infty}^{\infty}\left[\sum_{i=1}^{N_1-1}(\bar{J}_{ni}^{t}I_{ni}^{te}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset e})+\sum_{i=N_1}^{N_1+N_2+N_3}(\bar{J}_{ni}^{t}I_{ni}^{t}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset})+\sum_{i=N_1+N_2+N_3-2}^{N_t-5}(\bar{J}_{ni}^{t}I_{ni}^{te}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset e})\right] \quad (8)$$

$$(\bar{J}_{cd}+\bar{J}_{de})=\sum_{n=-\infty}^{\infty}\left[\sum_{i=1}^{N_6+N_7-2}(\bar{J}_{ni}^{t}I_{ni}^{td}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset d})+\sum_{i=N_6+N_7-1}^{N_6+N_7+N_2+N_3-4}(\bar{J}_{ni}^{t}I_{ni}^{t}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset})+\sum_{i=N_6+N_7+N_2+N_3-3}^{N_t-7}(\bar{J}_{ni}^{t}I_{ni}^{td}+\bar{J}_{ni}^{\emptyset}I_{ni}^{\emptyset d})\right] \quad (9)$$

Selection of the weighting function (W) is a necessary step in the method of moment. We use the Galerkin technique, which is considered one of the most convenient. In this method, the weighting function is equal to the complex number of the primary function of current (W=J^*), so the weighting function can be described as follows:

$$\bar{W}(\bar{r})=\bar{W}^{t}(t\text{‘}\emptyset)+\bar{W}^{\emptyset}(t\text{‘}\emptyset)=\sum_{m=-\infty}^{\infty}\sum_{i=1}^{N-10}\left[\bar{W}_{mi}^{t}(t\text{‘}\emptyset)+\bar{W}_{mi}^{\emptyset}(t\text{‘}\emptyset)\right] \quad (10\ a)$$

$$\bar{W}_{mi}^{t}(t\text{‘}\emptyset)=\hat{u}_{t}f_{i}(t)e^{-jm\emptyset} \quad (10\ b)$$

$$\bar{W}_{mi}^{\emptyset}(t\text{‘}\emptyset)=\hat{u}_{\emptyset}f_{i}(t)e^{-jm\emptyset} \quad (10\ c)$$

Using the numerical multiplication of the weighting function with equations (7) that to obtain the following matrix form:

$$\begin{bmatrix} [Z^{1e}_{ce,ce}]_n & [0]_n & [Z^{2e}_{ce,de}]_n & \eta_e[Y^{3e}_{ce,de}]_n \\ [0]_n & [Z^{1d}_{cd,cd}]_n & [Z^{2d}_{cd,de}]_n & \eta_e[Y^{3d}_{cd,de}]_n \\ [Z^{1e}_{de,ce}]_n & [Z^{1d}_{de,cd}]_n & [Z^{2e}_{de,de}+Z^{2d}_{de,de}]_n & \eta_e[Y^{3e}_{de,de}+Y^{3d}_{de,de}]_n \\ [Y^{1e}_{de,ce}]_n & [Y^{1d}_{de,cd}]_n & [Y^{2e}_{de,de}+Y^{2d}_{de,de}]_n & \eta_e[Z^{3e}_{de,de}+Z^{3d}_{de,de}]_n \end{bmatrix} \begin{bmatrix} [I^{1e}]_n \\ [I^{1d}]_n \\ [I\ ]_n \\ [K\ ]_n \end{bmatrix} = \begin{bmatrix} [0]_n \\ [V^{d}_{cd}]_n \\ [V^{d}_{de}]_n \\ [I^{d}_{de}]_n \end{bmatrix} \quad ...(11)$$

From the above equations, it is possible to calculate the radiation fields of the antenna in this study in the area of the far field (external valence region) from knowing the currents, where the equations are used that can be found: [11]

$$E_\theta = \frac{-jw\mu_e}{4\pi r_\circ} e^{-jk_e r_\circ} \int_s \left(\bar{J}(\bar{r}').\hat{\theta} + \frac{1}{\eta_e} \bar{M}(\bar{r}').\hat{\emptyset} \right) e^{-jk_e \hat{r}_\circ.\bar{r}'}\, ds \qquad ...(12\,a)$$

$$E_\emptyset = \frac{-jw\mu_e}{4\pi r_\circ} e^{-jk_e r_\circ} \int_s \left(\bar{J}(\bar{r}').\hat{\emptyset} - \frac{1}{\eta_e} \bar{M}(\bar{r}').\hat{\theta} \right) e^{-jk_e \hat{r}_\circ.\bar{r}'}\, ds \qquad ...(12\,b)$$

$(r_\circ, \theta_\circ, \emptyset_\circ)$ is the vector units of a point in the far field.

2. Computed Result and Discussion

We explain the results obtained for the short backfire antenna by programming the relationships for the short backfire antenna, which were analyzed by applying the moment of method, and compared with Ehrenspeck H. W. [12]. In order to validate the mathematical and programmatic treatment that was adopted in our research, the experimental investigation of SBFA was used to validate the results of the numerical study, see figure (3). This fig. represents a comparison of the results of this work of the radial structures emitted at the electrical and magnetic fundamental plane (E - plane and H-plane). The results are highly agreement with Ehrenspeck H. W and Z. A. Ahmed [12] [13]. For the same dimensions in Table (1-1)

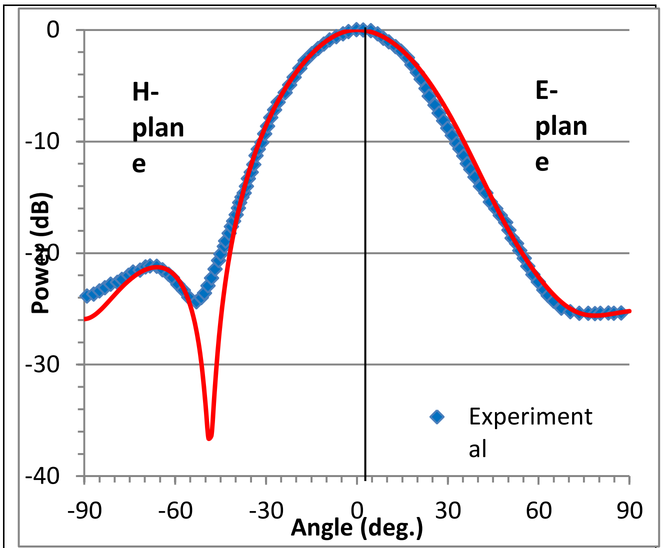


Fig. 3. Compare Radiation pattern of SBFA between MoM and Exp.

a) Excitation voltage: - The secondary excitation matrices of the tangential compounds V^t and $I^\emptyset$ are plotted in Figs (4) and (5), respectively. The first figure (4) shows that the voltage value of both components (φ ^, t ^) is higher in the main reflector than in the sub-reflector and increases gradually.

As for Figure (5) of the coaxial voltage matrix, the voltages are only in the insulating region, due to the boundary conditions of the electromagnetic currents of the conductive and insulating surfaces, and its value begins to decrease.

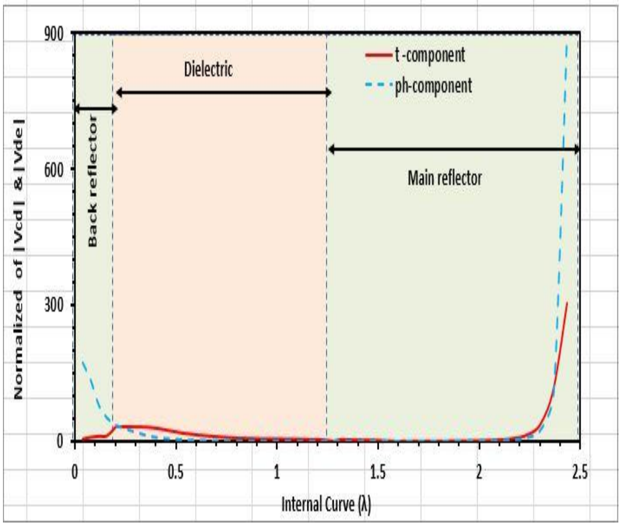


Fig. (4) Normalized of [V_{cd}] & [V_{de}]

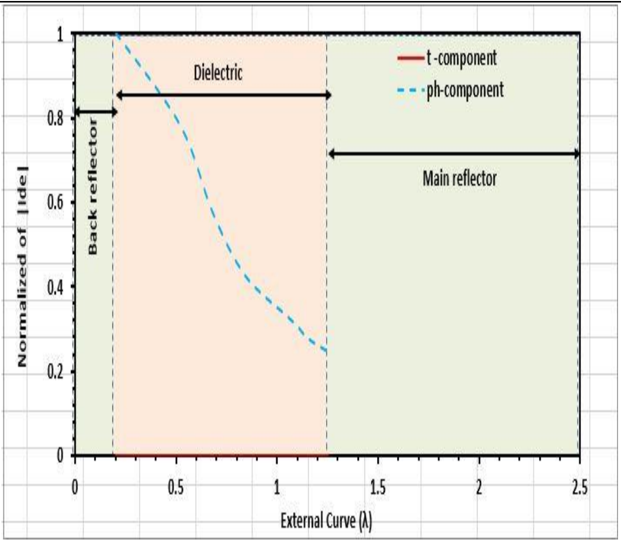
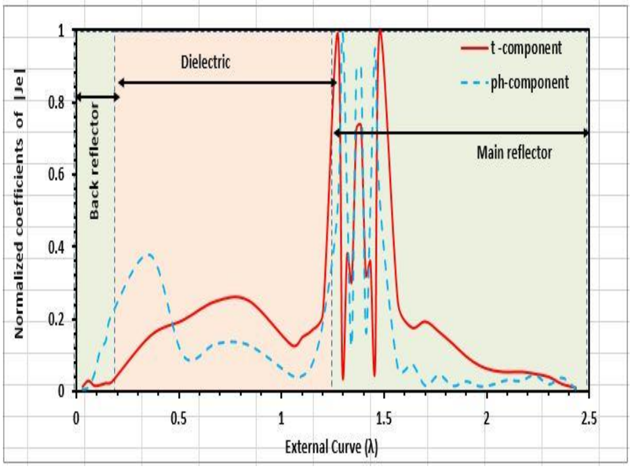
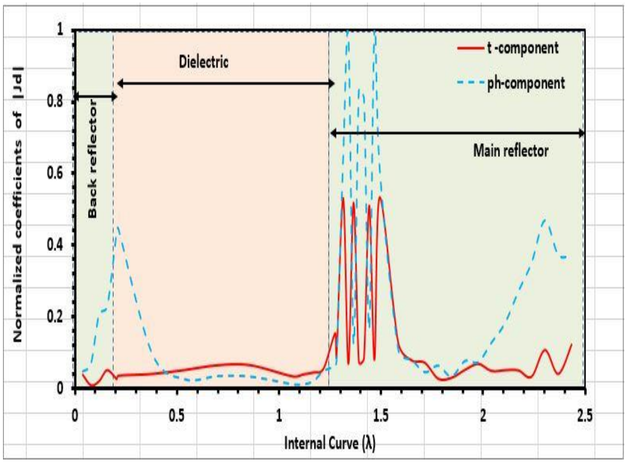


Fig. (5) Normalized of [I_{de}]

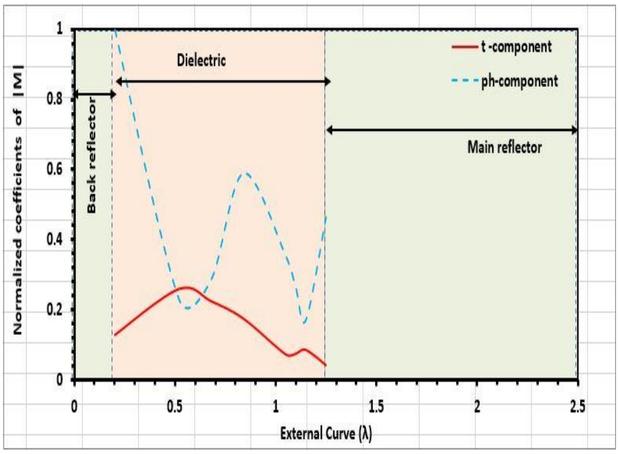
b) surface currents: - The current distribution is treated here as unknown. This method (MoM) involves segmentation of the body and choosing suitable, the unknown surface currents on the SBFA as a BoR are decomposed into two components along the unit vector $\hat{u}_t$ and $\hat{u}_\emptyset$. Where the figure (6, a,b) shows,that the greatest value of the coefficients of electric currents is on the surface of the main reflector and the lowest values are in the insulating area and the sub-reflector. Where the electric currents induced on the surface of the reflector are a source in determining the radiative structures.



(a)



(b)



(c)

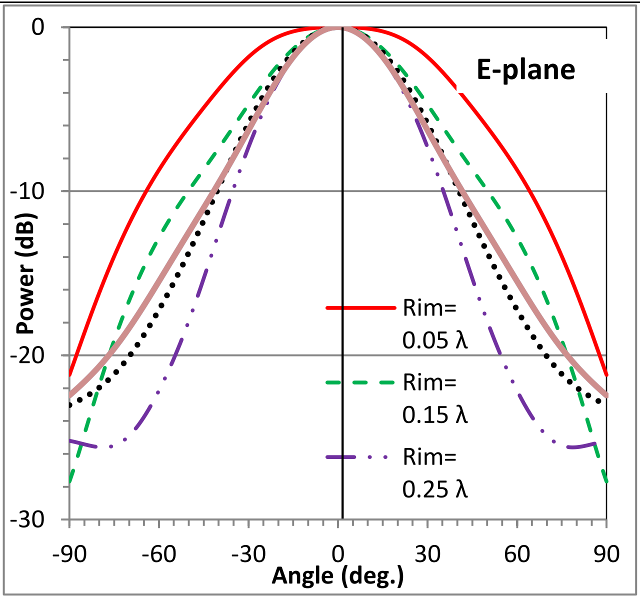
Fig (6) The density of the Electric $|Jn|$ and Magnetic $|Mn|$ currents that propagate on the outer and inner surfaces of short backfire antenna

While Figure (6 c) shows the surface density of the magnetic current spread on the inner surfaces of the conductive materials S_{cd}

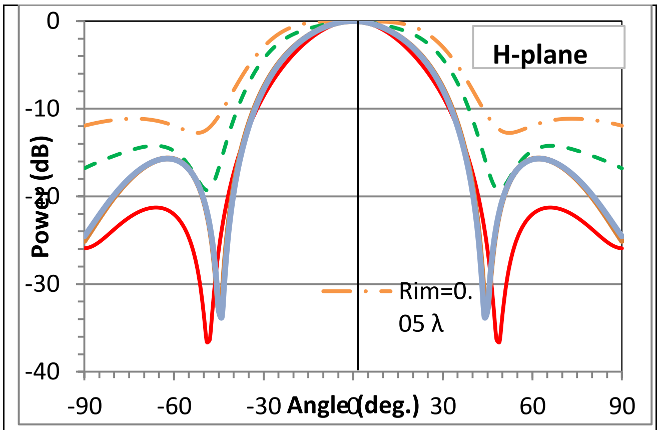
and the dielectric S_{de}, and we note that the coaxial and tangential components are equal or identical to a large extent with a significant increase in the coaxial component in the main reflector area.

In order to obtain the maximum directivity and effectivity from the short backfire antenna (under consideration), the rim width and the antenna dimensions must have the best values.

Now, we carried out a theoretical study of the parameters antennas and their results effect on of the directivity. First, the computed E- and H-plane radiation patterns are plotted in Fig. (7) for various values of rim width W_{rim} and constant values of two reflectors and distance between them. The primary lobe beam width decreases with increasing W_{rim}, however the range of side lobes additionally increases, since b determines the measurement of the aperture. the maximum directivity is got with W_{rim} = 0.25 λ. This value is approximately the same as the experimental described by [13].



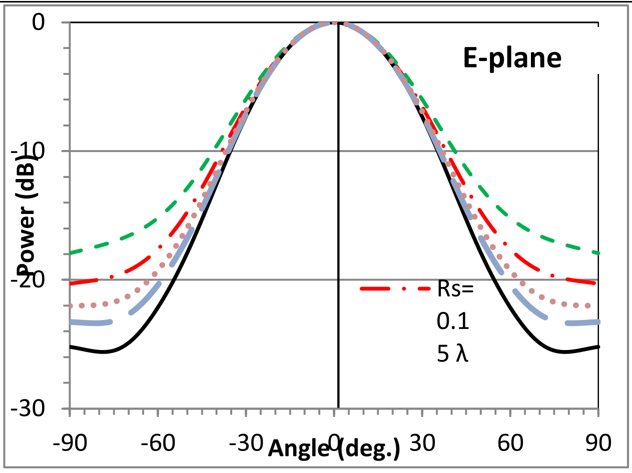
(a)



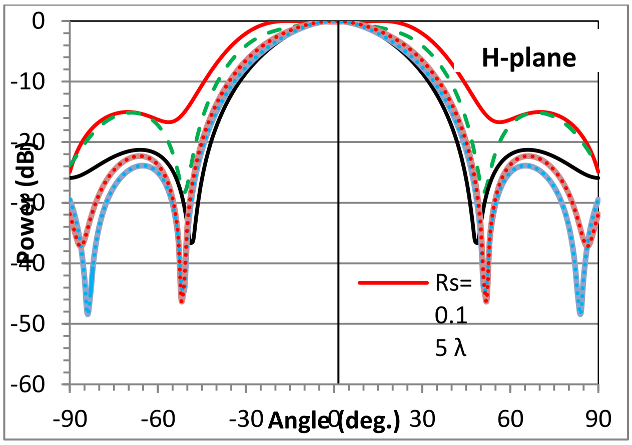
(b)

Fig. 7 Computed *E*- and H-plane radiation patterns for different rim width.

Then, we review the effect of changing the diameter of the reflector. Several values ranging between (0.15 λ) and (0.25 λ) were tested for the **small reflector** R_s, and the optimum value of (0.20λ) was presented in the measurement of the antenna radiation pattern for the E and H levels, at which the greatest directivity occurs. As in Figures below, (8a) and (8b), below, at the fixed frequency of 3 GHz. Where it is noticed from the first figure that with increasing the radius of the reflector, the beam width and side lobe level will improve on both the H plane, and it reaches the optimum value, after which the pattern deteriorates, which leads to an increase in the beam width on a wider scale and an increase in the side lobe level, which leads to Decrease in gain. The very small values of this reflector transform the backfire antenna into a normal end-fire antenna and reduce the directivity. On other hand the excessive values of the small reflector diameter close to the large reflector diameter also decrease the antenna directivity because of a reduction of the aperture region.

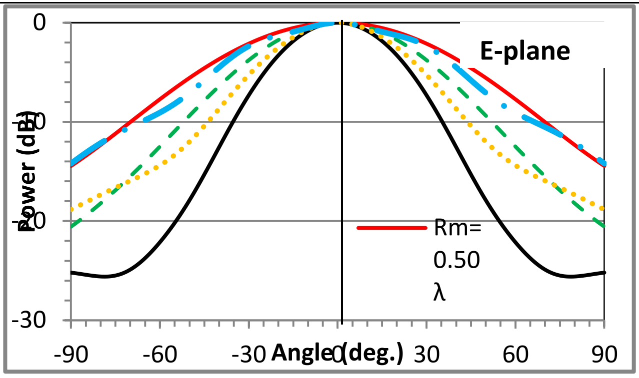


(a)

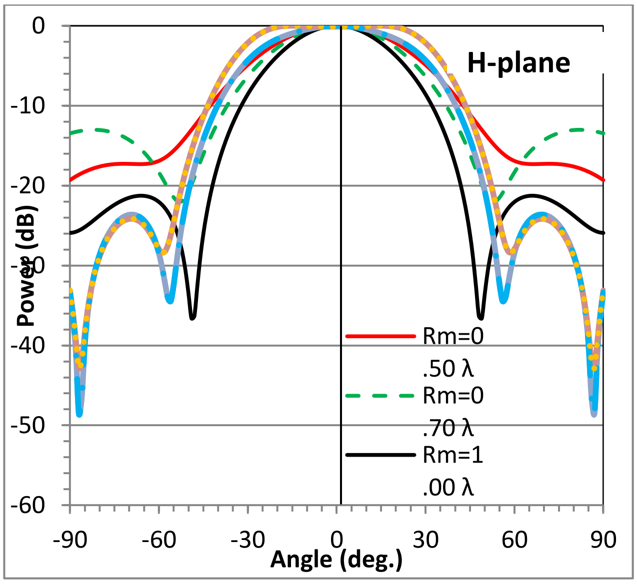


(b)

Fig. 8 Computed *E*- and H-plane radiation patterns for different sub-reflector radius.



(a)



(b)

Fig. 9 Computed *E*- and H-plane radiation patterns for different main-reflector radius.

The radiation patterns of the E and H planes, computed in Figures 9 (a) and (b), are drawn for different values of the radius of the large reflector, which start from (0.5 λ) to (1.5 λ). The maximum directivity is obtained at (1.0λ). We notice that the width of the main lobe beam begins to decrease with increasing the radius until we reach the optimum value corresponding to the experimental results, but the number of side lobes also increases with the increase of the radius more than (1.0λ) and thus this increase will have a negative effect and reduce the antenna directivity.

Table 2 shows the investigation of the directivity value theoretically and are in agreement with the experimental value.

Table 2 Directivity with different value for each (Rim, Rs, Rm)

Rim (λ)	D(dB)	Rm (λ)	D(dB)	Rs (λ)	D(dB)
0.05	12.26	0.5	10.7	0.15	10.7
0.15	12.36	0.7	12. 6	0.17	12.6
0.25	14.79	1.0	14.8	0.20	14.79
0.35	13.9	1.2	13.7	0.23	12.5
0.45	14.11	1. 5	9.76	0.25	13.9

3. CONCLUSION

The aim of the work carried out recently was to analysis short backfire antenna by using moment method. SBFA, which was studied during in this paper, is one of the efficient radioactive elements that can be used to form linear and surface arrays for several reasons, including its high directivity and small size. A modified type rim of the antenna is introduced. The effect of change the dimensions of the rim on the antenna directivity is presented. Numerical results of our suggested antenna show a good qualitative agreement between previous studies, which confirmed the general validity of the model used for analytic these type of projects. It is worth mentioning that the proposed antenna has a lot of applications, especially in the military equipment and air crafts.

4. REFERENCES

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