BACKFIRE ANTENNA WITH MULTIPLE FLAT REFLECTORS AND RECTANGULAR APERTURE AS FEED ELEMENT

R. AL-RASHID*
A.Y. HUSSAIN*

SUMMARY: The backfire principle is an effective technique for improving the performance of an antenna, without adding much to its physical dimensions or weight. In this paper a backfire antenna with multiple flat reflectors is suggested. The performance of this backfire antenna is compared with those of a single and double back reflector backfire antennas operating at the same design frequency of 9.35 GHz. The measurements indicate a remarkable improvement in the gain and mainlobe to sidelobe-level and a significant increment in the bandwidth of the antenna. The dimensions of the antenna are optimized to give maximum directive gain.

Key Words: Backfire antenna.

INTRODUCTION

The backfire antenna as originally proposed by Ehrenspeck (6-9) is essentially a leaky cavity structure consists of surface wave structure as feed element placed between two plane reflectors of different sizes. The small reflector together with the feed element form an endfire structure that illuminates the back reflector which will reflect the incident wave causing superposition with the direct outgoing wave. Various forms of feed elements were used in exciting the backfire antenna and many improvements were achieved by trying different shapes and sizes of reflectors or adding a rim to the back reflector (2,5,10-13). Among other structures implemented in exciting the backfire structure were the open-ended waveguides which are suitable for applications in the microwave frequency bands (1,3,4,11,12,19,18).

The backfire antenna suggested in this paper consists of a rectangular waveguide aperture as feed element with different combinations of flat front and back reflectors.

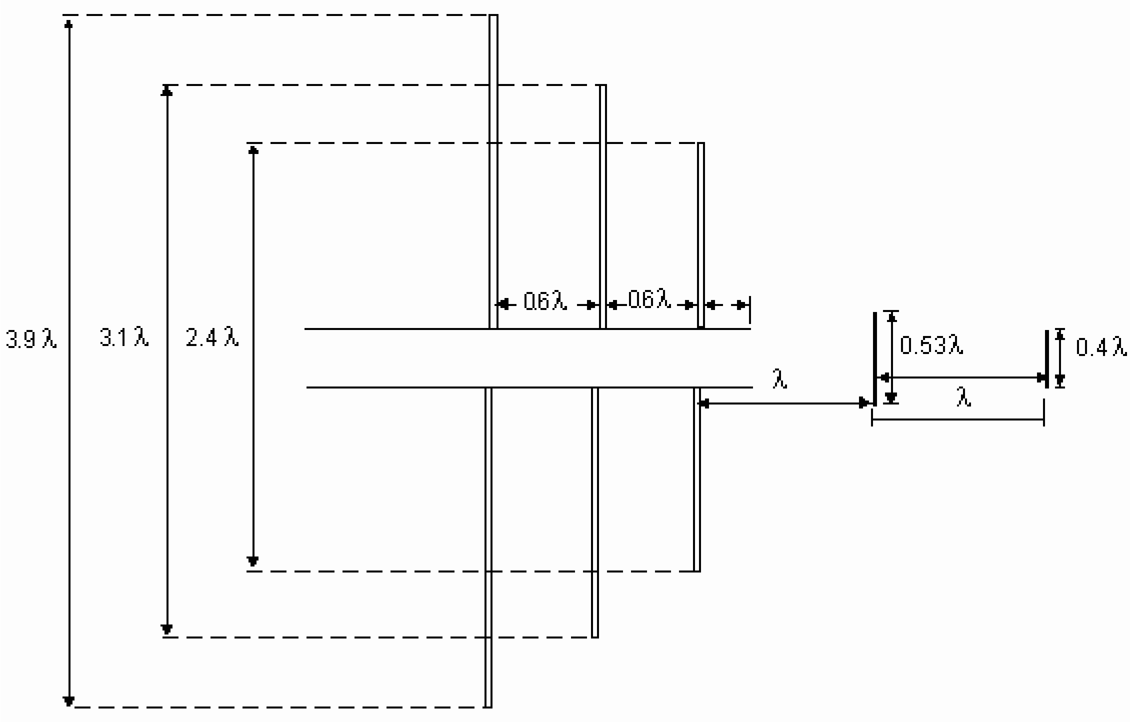
MATERIALS AND METHODS

Antenna Design

In previously published papers, Al-Rashid *et. al.* (2-4), have shown that adding a second flat back reflector to the ordinary backfire antenna resulted in a considerable improvement in the performance of the antenna. The aim of this paper is to investigate the performance of a rectangular wave guide-fed backfire antenna with different combinations of multiple front and back reflectors. The design frequency of the antenna was in the x-band region at 9.35 GHz. Five backfire antennas with different combinations of front and back reflectors were constructed and investigated. The best experimental results were found with the combination of triple back reflectors and double front reflectors were of circular shape of diameters of 2.4λ, 3.1λ and 3.9λ respectively, where λ is the wavelength in

*From Department of Physics, College of Science Saddam University, Baghdad, Iraq.

Figure 1: The backfire antenna with its optimum dimensions.



free space. The front reflectors were of elliptical shape of axes A and B of 1λ and 0.53λ for the first front reflector and 0.8λ and 0.4λ for the second reflector. The effect of the shape and size of the first front reflector on the gain of the antenna is shown in Table 1. The final structure of the backfire antenna with its optimum dimensions is shown in Figure 1. The two front reflectors are supported on a foamed dielectric with relative permittivity very close to unity.

Table 1: The effect of shape and size of the first front reflector on received power.

Shape of Reflector	Dimensions	Pr (dB)
Circular	D= 0.75	8.4
Circular	D=0.5	8.0
Elliptical	AxB= 0.46 x 0.93	8.7
Elliptical	AxB= 0.4 x 0.8	9.0

RESULTS

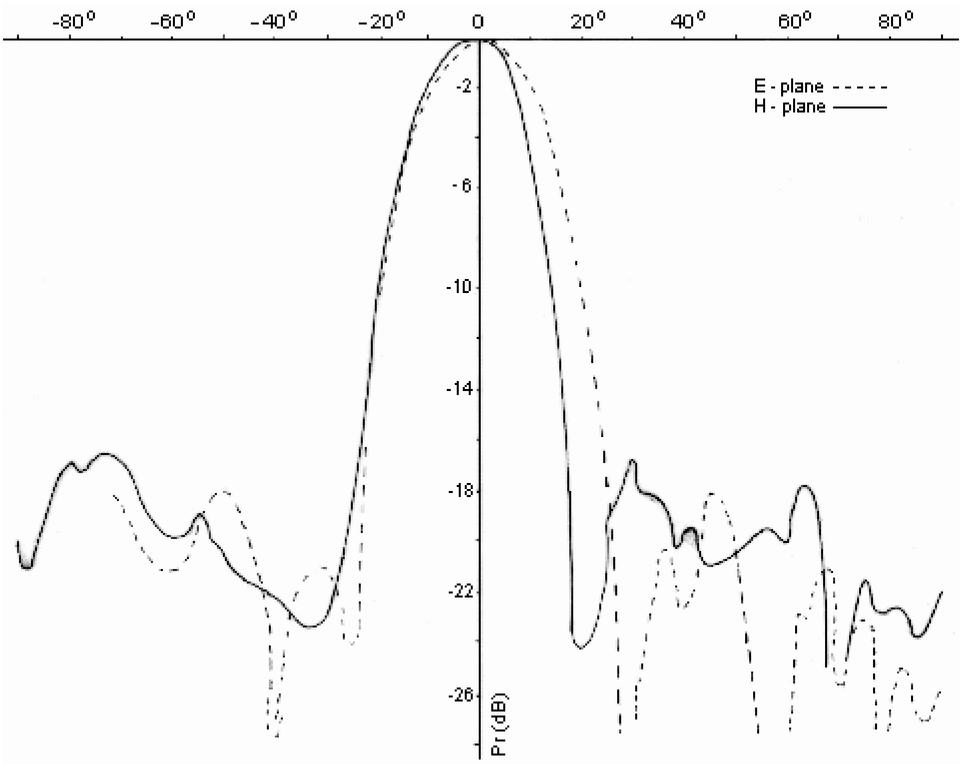
Using the same principle mentioned in (16-18) five different backfire antennas with rectangular waveguide aperture feed element and multiple front and back reflectors have been constructed and investigated. These were:

1. Backfire antenna with single front and single back reflector. [Antenna No. (1)].
2. Backfire antenna with single front reflector and double back reflectors. [Antenna No. (2)].
3. Backfire antenna with single front reflector and triple back reflectors. [Antenna No. (3)].
4. Backfire antenna with double front reflectors and double back reflectors. [Antenna No. (4)].

Table 2: Variation in directive gain for different types of backfire antenna.

Type of Antenna	Measure G (dB)
Bacfire antenna No. 1	13.3
Bacfire antenna No. 2	16.6
Bacfire antenna No. 3	17.0
Bacfire antenna No. 4	17.1
Bacfire antenna No. 5	17.7

Figure 2: The power pattern characteristics for the E-plane and H-plane.



5. Backfire antenna with double front reflectors and triple back reflectors. [Antenna No. (5)].

a- The Gain:

The directive gain of the different types of backfire antennas mentioned before was measured. The results are summarized in Table 2. Experimentally the highest value of the gain was that of the backfire antenna with double front reflectors and triple back reflectors. The gain was found to be 17.7 dB, and this is an improvement of 4.4 dB above that of the backfire antenna No. (1) and 1.1 dB above that of the backfire antenna No. (2).

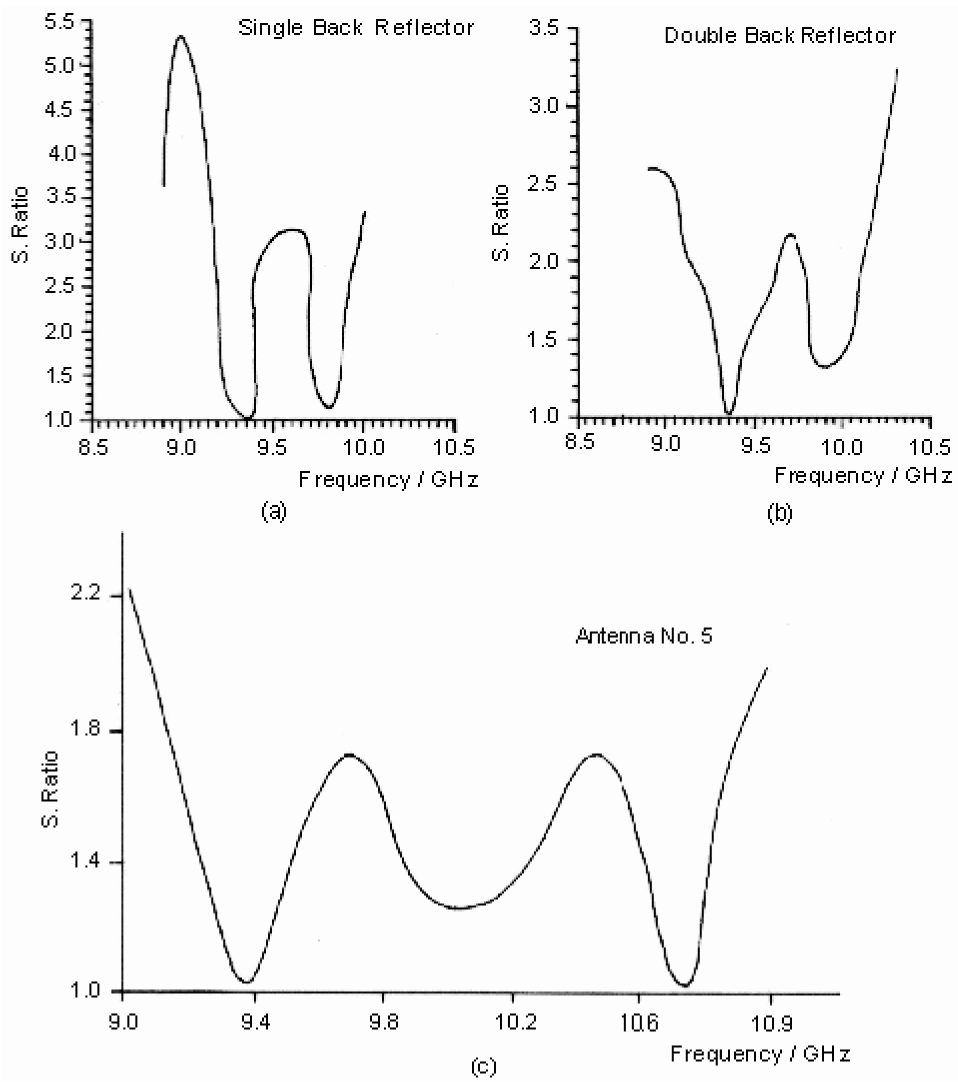
b- The Radiation Pattern:

The radiation power pattern of the backfire antenna with triple back reflectors and double front reflectors was measured at the design frequency of 9.35 GHz and is displayed in Figure 2 for both the E- and the H-plane. The measured beam width in the E- and the H-plane were 21° and 20° respectively. The sidelobe level was 18 dB below the mainlobe level for the E-plane and 16.6 dB below the mainlobe level for the H-plane. This is an improvement of 3 dB for the E-plane and 4.4 dB for the H-plane with respect to that of the backfire antenna with double back reflectors and single front reflector. Inspection of Figure 2 indicates that the modified backfire antenna has a symmetrical radiation pattern in both the E-plane and the H-plane.

c- The Band Width:

The band width is the region between two frequencies at which the antenna operates at good condition. Figures (3-a, b and c) show the variation of S-ratio with the frequency for three backfire antenna types, these are antennas numbers 1, 2 and 5. Inspection of these figures show the effect of adding front and back reflectors on the band width of the backfire antenna. The S-ratio was below 1.02 at design frequency for all three

Figure 3: S. ratio variation with frequency.

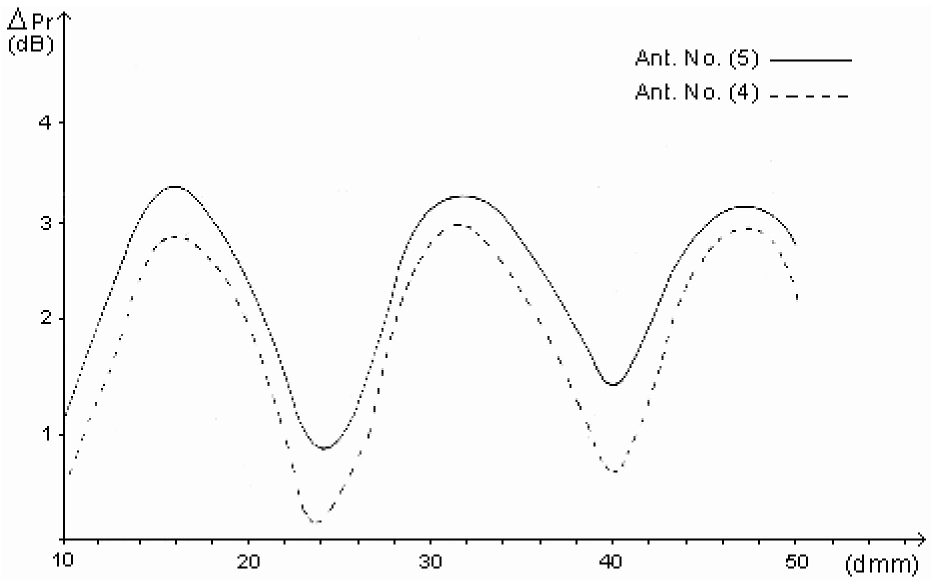


types of backfire antenna. The value of S-ratio was below 2 for the frequency range of (9.21-9.44) GHz for backfire antenna number 1, this is equivalent to a percentage band width of 2.5%, whilst this values of S-ratio was within the frequency range of (9.15-9.59) GHz, which is equivalent to a percentage band width of 4% for backfire antenna number 2. The same value of S-ratio was within the range of (9.1-11.0) GHz for backfire antenna number 5, which is equivalent to a percentage band width of 20%. Comparing these results we find that there is an increment of 16% in the percentage value of the band width of backfire antenna number 5 with respect to that of backfire antenna number 2. Moreover these figures show that the value of S-ratio approachs its initial value of (1.02) again for a second value of frequency, when the number of reflectors increases. The S-ratio returns back exactly to its initial value of (1.02) at the frequency of (10.76) GHz for the backfire antenna number 5. This means that the backfire antenna number 5 seems to be a dual frequency antenna.

d- The Second Front Reflector:

The received power was investigated as a function of the distance between the two front reflectors. This

Figure 4: Variation of received power with (d), the distance between the front reflectors for two types of backfire antenna.



has been done for two types of backfire antennas, these were backfire antennas numbers 4 and 5. The results are illustrated in Figure 4. From this figure one can conclude that the maximum received power occures when the distance between the two front reflectors is equal to n $\lambda/2$, where n=1,2,3,....... Table 3 gives a comparison summary for the performance of three types of backfire antenna with different combinations of front and back reflectors.

CONCLUSION

The performance of a backfire antenna with single front reflector and double back reflectors has been significantly improved by adding a third back reflector and a second front reflector to the initial antenna. The reported results indicate that this antenna has a higher directive gain, an improved mainlobe to sidelobe level and a noticeable increment in the band width of the antenna. Moreover the measurements of the band width indicate that the modified backfire antenna is capable of providing dual frequency operation. This phenomenon is useful in situations where the antenna is required to operate efficiently at two distinct frequencies. This rigid, light weight compact antenna can be suggested for use in different communication purposes.

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Table 3: Comparison summary for the performance of three backfire antenna types.

Type of Antenna	Gain (dB)	Halfpower B.W. (degree)		Mainlobe to Sidelobe level (dB)		Band With (GHz)
		E-plane	H-plane	E-plane	H-plane	
Backfire Antenna No. (1)	13.3	29°	21°	10	11	9.21-9.44
Backfire Antenna No. (2)	16.6	21°	21°	15	12	9.15-9.59
Backfire Antenna No. (5)	17.7	21°	20°	18	16.6	9.10-11.0

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Correspondence:
R. Al-Rashid,
Department of Physics,
College of Science,
Saddam University,
Baghdad, IRAQ.