SHORT BACKFIRE ANTENNA WITH DOUBLE FLAT BACK REFLECTOR AND RECTANGULAR APERTURE AS FEED ELEMENT

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SUMMARY : A double back reflector short backfire antenna is constructed and investigated. The performance of the antenna is compared with that of a single back reflector short backfire antenna at the design frequency of 9.35 GHz. The dimensions are optimized to give a maximum directive gain. The gain, the half power beam width and the band width of the antenna are improved without adding much to antenna weight, size or cost.

Key Word : Backfire antenna.

INTRODUCTION

Short backfire antennas are very convenient as antennas of directive gain in the range of 15-30 dB. Due to their favorable radiation pattern characteristics, small size and low cost, they are very useful in arrays of high gain antennas for satellite communication, Doppler Sensing, telemetry and ship and aircraft communication. The backfire antenna consists of a surface wave structure placed between two plane reflectors of different sizes (1-4). The small reflector together with the feed element form an end fire structure that illuminates the back reflector which in turn reflects the incident wave causing super position with the direct outgoing wave (2, 4).

Many improvements were made by choosing different shapes and sizes of reflectors or adding a rim to the back reflector. Various feed elements have been used to excite the antenna (2, 5-7). Recently a new type of short backfire antenna consisting of two back reflectors has been suggested (8). Following the same principle, using a rectangular aperture as feed element, a short backfire antenna has been constructed and investigated in this paper. The SBA with its optimum dimension is shown in Figure 1.

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Antenna design

A single back reflector backfire antenna with optimum dimensions was first designed and tested. Different sizes and shapes of the front and back reflectors are tried to give maximum directive gain. The results are summarized in Tables 1 and 2.

The optimum dimensions of the backfire antenna with single back reflector were found to be :

- The front reflector was elliptical with axes A and B of 0.9 λ and 0.4 λ respectively, λ being the free space wavelength (λ= 3.2 cm).

- The diameter of the circular back reflector was 3.5 λ.

- The insertion depth of the rectangular wave feed into the back reflector was 0.7 λ.

- The distance between the front and the back reflector was 1.5 λ.

The front reflector is supported on a foamed dielectric with dielectric constant very close to unity.

The gain of the backfire antenna with single back reflector was found to be 13.3 dB with an increment of 5.7 dB as compared to that of the rectangular aperture.

A second back reflector is then added to the antenna and the performance of the new antenna is studied for various combinations of back reflectors with different diameters. The results are shown in Table 3. All measurements were carried out in the x-band. The design frequency is 9.35 GHz.

Upon varying the combination of the double back reflectors an optimum radiation characteristic was obtained with a combination of diameters of 2 λ and 3.5 λ respectively.

RESULTS

The Gain

The directive gain of the double back reflector backfire antenna was found to be 16.6 dB, this is an improvement of 3.3 dB above that of a single back reflector backfire antenna.

The power pattern characteristics

The addition of a second back reflector has a great influence on the power pattern characteristic of the backfire antenna. The half power beam width for the double back reflector antenna was 21° for both E-plane and H-plane, while for that of single back reflector, the half power beam with was 29° in the E-plane and 21° in the H-plane. The side lobe level was -15.0 dB below the main lobe level for the E-plane and -12.8 dB for the H-plane, and that is an improvement of 5.0 dB in the E-plane and 1.8 dB in the H-plane with respect to that of single back reflector backfire antenna.

It is also found that the new backfire antenna has a symmetrical radiation pattern. The radiation pattern for the two antennas with single and double back reflector backfire antennas for the E-plane and H-plane are illustrated in Figures 2 and 3 respectively.

The Band Width

The S-ratio was below 1.01 for the double back reflector backfire antenna at design frequency and below 2 for the frequency range of (9.15-9.59) GHz, whilst this value of S was within the frequency range of (9.21-9.44) GHz for the single back reflector backfire antenna. The half power beam width was below 36° for both planes for the double back reflector backfire antenna within the frequency range (9.15-9.59) GHz. At frequency higher than 10 GHz, the main lobe divided itself.

Table 1: Improvement in received power due to shape and size of the front deflector for double back reflector short backfire antenna with large back reflector of diameter = 3.0 λ and small back reflector of diameter = 3.0 λ combination.

Type of front reflector	Dimensions	PR (dB) over that of rect. aper.
circular	0.8 λ	4.4
rectangular	0.9 λ x 0.4 λ	5.4
elliptical	0.9 λ x 0.4 λ	5.7
elliptical	1.1 λ x 0.6 λ	4.2

Table 2 : Improvement in received power due size of back reflector for single back reflector short backfire antenna with elliptical front reflector of axes A and B of 0.9 λ and 0.4 λ.

Diameter of back reflector	PR (dB) over that of rect. aper.
2.0 λ	5.3
2.5 λ	5.7
3.0 λ	5.3
3.5 λ	2.5
3.0 λ	5.3
4.5 λ	3.0
5.0 λ	5.7
5.5 λ	5.3
6.0 λ	4.7
6.5 λ	5.7

Table 3: Improvement in received power due size of back reflectors for double back reflector short backfire antenna with elliptical front reflector of axes A and B of 0.9 λ and 0.4 λ

Diameter of small back reflector	Diameter of large back reflector	PR (dB) over that of rect. aperture
2.0 λ	2.5 λ	7.9
	3.0 λ	7.4
	3.5 λ	8.8
	4.0 λ	5.1
	4.5 λ	6.3
	5.0 λ	6.5
	5.5 λ	7.4
	6.0 λ	7.3
	6.5 λ	8.6
	7.0 λ	6.8
2.5 λ	3.0 λ	7.4
	3.5 λ	8.6
	4.0 λ	5.7
	4.5 λ	7.6
	5.0 λ	8.0
	5.5 λ	7.6
	6.0 λ	7.8
	6.5 λ	7.7
	7.0 λ	7.4
3.0 λ	3.5 λ	7.1
	4.0 λ	6.4
	4.5 λ	8.4
	5.0 λ	7.9
	5.5 λ	5.8
	6.0 λ	6.4
	6.5 λ	7.4
	7.0 λ	8.8
3.5 λ	4.0 λ	3.3
	4.5 λ	5.7
	5.0 λ	5.3
	5.5 λ	6.0
	6.0 λ	5.7
	6.5 λ	4.7
	7.0 λ	4.9
4.0 λ	4.5 λ	7.2
	5.0 λ	7.9
	5.5 λ	8.7
	6.0 λ	8.4
	6.5 λ	8.2
	7.0 λ	7.4

Table 4: Side to main lobe level variation with respect to frequency for double back reflector short backfire antenna.

Freq. (GHz)	Left Side Lobe		Right Side Lobe		H.P.B.W (deg.)
	Pos. (deg.)	Level (dB)	Pos. (deg.)	Level (dB)	
8.5	63	-17.5	57	-16.0	26
8.6	60	-14.2	65	-17.5	25
8.7	60	-17.0	65	-16.0	27
8.8	60	-15.7	66	-14.1	29
8.9	60	-18.6	66	-16.2	21*
9.0	60	-16.5	66	-15.0	26
9.1	60	-14.9	63	-14.4	30
9.2	60	-15.0	57	-15.8	30
9.3	60	-14.8	57	-12.2	32
9.35	60	-16.4	57	-15.0	21
9.4	60	-16.5	57	-14.4	26
9.5	60	-16.5	57	-14.6	28
9.6	60	-15.9	57	-16.4	31
9.7	60	-16.3	57	-16.9	30
9.8	60	-16.4	57	-18.5	35
9.9	60	-15.5	57	-15.4	39
10.0	60	-9.7	57	-8.5	54

* Too many side lobes.

Table 5: Summary of results for the three antenna types.

Type of antenna	Gain (dB)	H.B.P.W. (Deg)		M/S Lobe (dB)		Bandwith (GHz)
		E-	H-	E-	H-	
Aperture	6.8	36.5	47.5	9.6	6.0	-
Single back reflector backfire	13.3	29	21	10.0	11.0	9.21-9.44
Double back reflector bacfire	16.6	21	21	15.0	12.0	9.15-9.59

Figure 1: The double back reflector backfire antenna with its optimum dimensions.

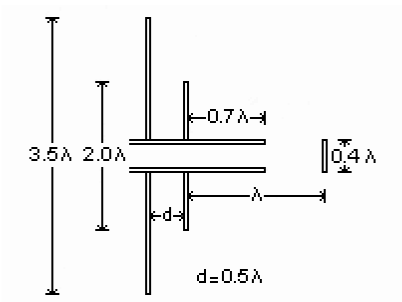

Figure 2: The power pattern characteristics for the E-plane.

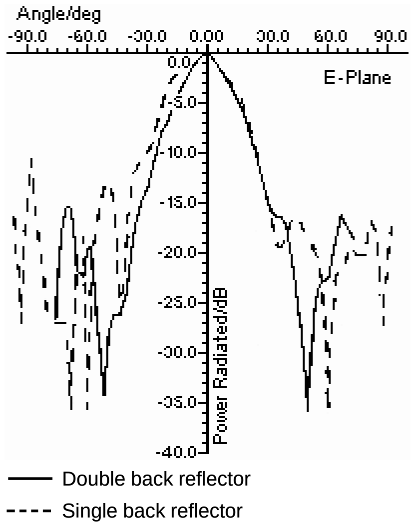

Figure 3: The power pattern characteristics for the H-plane.

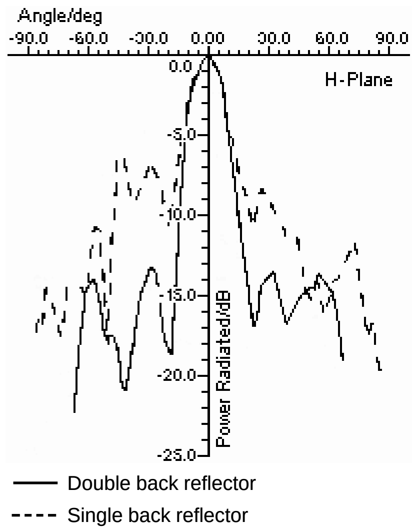

Figure 4: S-ratio variation with frequency for double back reflector short backfire antenna.

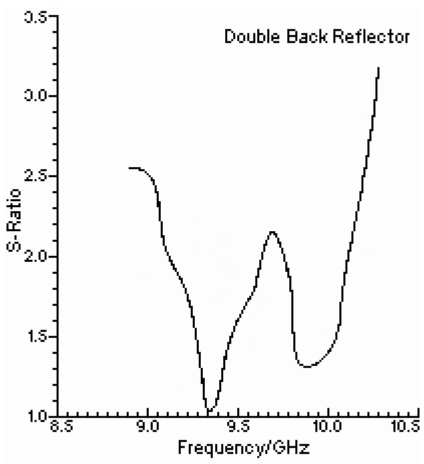

Figure 5: S-ratio variation with frequency for single back reflector short backfire antenna.

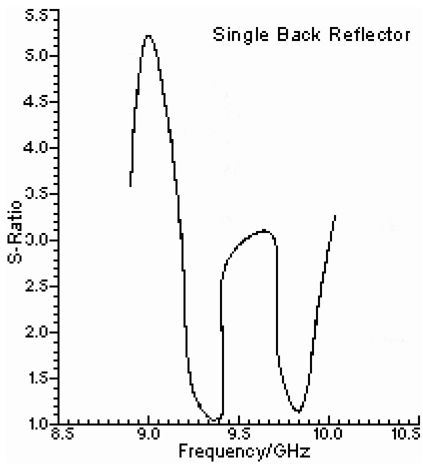

Table 4 shows the variation of main to side-lobe level ratio and half power beam width with frequency for the double back reflector backfire antenna in the E-Plane. Table 5 gives a comparison summary for the performance of the double back reflector backfire antenna, the single back reflector backfire antenna and the aperture. Figures 4 and 5 show the variation of S-ratio with frequency for the two antenna types.

CONCLUSION

Adding a second back reflector has remarkably improved the backfire performance without adding much to the antenna weight, cost or size.

The second back reflector effect can be studied using a backfire array. The variation in shape of the double back reflector upon the performance of the antenna can also be investigated.

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