Active minimization of the sidelobes of radiating apertures

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A novel technique for suppressing sidelobes as well as increasing the mainlobe level of radiating apertures is presented. The technique involves placing a separately excited wire along the diffracting edge of the aperture so as to enhance the mainlobe and to suppress the sidelobes of the radiating aperture. The beamwidths of the resulting $E$ and $H$ planes of a circular waveguide loaded by an active wire loop are found to be almost identical in a particular experimental case. Furthermore, the $E$ and $H$ plane patterns approach each other since the sidelobe levels are decreased significantly in the $E$ plane and by about the same amount as they are increased in the $H$ plane. A significant increase in the main-to-sidelobe ratio is also obtained when this technique is applied to radiating fields from circular apertures in a full conducting plane and to the diffraction from apertures between two semi-infinite conducting wedges.

1. Introduction

For high gain antennas with low spillover and low cross-polarization, the feed should have the same aperture field distribution in the $E$ and $H$ planes. One of the simplest feeds is the open ended rectangular waveguide or small pyramidal horn operating in the $\text{TE}_{01}$ mode. One drawback of this type of feed is that it can only be used for linear polarization. For dual or circularly polarized systems the circular waveguide or conical horn is more useful. The field incident upon the aperture of a circular waveguide can be calculated exactly, as shown by Collin (1985), and therefore it is possible to find the theoretical performance of an open-ended cylindrical waveguide radiator.

Potter (1963) was the first to use a multimode horn to obtain a prescribed aperture field. In his design, the $\text{TM}_{11}$ mode was added in the proper phase with the $\text{TE}_{11}$ mode to obtain equal $E$ and $H$ plane radiation patterns. In the Potter horn, mode conversion was accomplished by a rapid change in the radius of a cylindrical waveguide. After a phase matching section, the horn then flares toward the aperture. The phase matching section is necessary so that the two modes add with the correct phase at the aperture. Turrin (1967) presented another more simple design which facilitates mode conversion by making an abrupt junction at the throat area of a conical horn. However, his design does not produce equal aperture field distributions in the $E$ and $H$ planes. Another simple method of obtaining a dual mode feed is to excite the $\text{TM}_{11}$ mode with an internal bifurcation junction, as was done by Schilling (1982). This design depends on the distance between the aperture and the...
internal waveguide to obtain the correct addition of the two modes at the aperture. An alternative method of mode conversion in a cylindrical waveguide was developed by Agarwal and Nagelberg (1970). They placed a dielectric ring at the discontinuity of two circular waveguides of different radii. A simple and effective dual mode horn was later designed by Satoh (1972). Satoh's horn uses a dielectric ring mounted at a strategic place on the walls of a conical horn. An extension of the Satoh horn has been developed by Wong and Brandt (1979) involving concentric dielectric rings placed in a conical horn. There are several other structures that support hybrid modes to achieve the same objective. Among these are the dielectric loaded circular waveguide (Claricoats and Taylor 1964), the corrugated horn (Claricoats and Olver 1984), the dieiguide (Claricoats and Salema 1973), the dielectric-filled conical horn (Lier 1986), the absorber-lined conical horn (Knop et al. 1986) and the large-diameter waveguide with impedance wall (Dragone 1981, Stanier et al. 1986).

In this communication, an active technique is proposed whereby a circular loop exciting the TM₁₁ mode inside a circular waveguide operating in the TE₁₆ mode is introduced and found to compete favourably with previous methods to produce almost equal E- and H-plane patterns. Further, the technique is also applied to enhance the mainlobe of the transmitted field through a circular aperture by exciting a circular loop placed near the edge of the aperture and the field diffracted by the aperture between two semi-infinite conducting wedges by using active sources with different amplitudes and positions.

2 Experimental set-up and procedure

A circular aluminium waveguide 30.8 cm long, 8.4 cm radius and 0.65 cm wall thickness was attached to a tapered section acting as a feed and the assembly mounted on a mechanical arm in an anechoic chamber. A longitudinal slot of 7 cm length and 0.7 cm width was cut in the wall of the waveguide. It should be noted that the measurements of the circular waveguide radiation patterns before and after cutting the slot did not indicate significant changes in the radiation pattern envelope.

An insulated copper wire was then formed into a loop and mounted on a sliding bracket surrounding the waveguide to permit external sliding of the loop as shown in Fig. 1. The loop was inserted into the waveguide through the slot which was divided into ten equal intervals. A coaxial cable at 6 GHz was used to excite the loop by using a Narda adder. The leads from the power source were fed into the adder, which split the power into two paths. One path fed the compensating loop while the other path fed the conical horn.

It is to be noted that the beginning of the slot was located 18 cm behind the aperture in order to enable the TM₁₁ mode of the loop and the TE₁₆ mode of the waveguide to become superimposed. At each location, the whole apparatus was matched with VSWR less than 1.02 and the E and H plane patterns were taken in order to find the optimum loop position, and excitation for the highest gain and lowest sidelobe level possible. The amplitude and phase of the loop current were adjusted to an optimum level so that the effect of diffraction from the waveguide circular edge was greatly minimized by a circular loop of almost equal diameter and optimum location.
3. Results and conclusion

The optimum location was found to be at 22.7 cm from the aperture plane of the circular waveguide. This position was the optimum position for the lowest sidelobes in the $E$ plane. Figure 2 shows the $E$ plane pattern with and without the loop. It is noticed that the sidelobe levels due to loading by the loop are significantly reduced for all observation angles between $\pm 65^\circ$ and $\pm 120^\circ$ with respect to the unloaded case. The sidelobe levels of the corresponding $H$ plane pattern did indicate almost equal increase as shown in Fig. 3. Furthermore, it is worth mentioning that the beamwidth of the $E$ and $H$ plane patterns of the loaded waveguide are 48° and
Figure 2. $E$-plane far field power patterns of a circular waveguide.

Figure 3. $H$-plane far field power patterns of a circular waveguide.
47.1°, respectively. This shows a difference in beamwidths equal to 0.9°, whereas the corresponding difference for the unloaded waveguide is about 10°.

In addition to the above experiment, a wire loop located along the edge of a circular aperture in a full perfectly conducting sheet was also used to modify the transmitted field pattern through the aperture due to a normally incident plane wave. For a circular aperture of 8.25 cm at 300 MHz, the ratio of the main-to-sidelobe levels of the transmitted field was increased by approximately 5 dB relative to the unloaded aperture as shown in Fig. 4. Furthermore, a double conducting wedge forming a slit type geometry was also loaded by multiple active sources to improve its diffraction characteristics. For a specific case the ratio of the main-to-first sidelobe level was increased by at least 7 dB (Elsherbeni and Hamid 1987).

The results obtained in this experiment show the validity of the new technique for producing almost equal $E$ and $H$ plane patterns. Further testing should prove that inserting a separately excited loop inside a waveguide is a definite alternative to presently used methods for suppressing sidelobes. The technique used in this communication is presently being extended to conical waveguides, parabolic reflectors and horn antennas using single or multiple wire sources; the results will be reported in future articles.

**REFERENCES**

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