A compact, aperture-matched, balanced transmission line antenna+

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ABSTRACT

This paper describes a novel balanced transmission line antenna where the maximum separation between the two conductors is only a fraction of a wavelength at the lowest operating frequency. The balanced transmission line is formed by exponentially extending the ridges of a double-ridged waveguide. The poor VSWR and patterns caused by reflections from the tips of the ridge extensions are improved by a combination of aperture matching and the use of microwave absorber. Measured VSWR, radiation pattern and gain data are presented for this compact, broadband antenna over the 2 to 11 GHz frequency range.

INTRODUCTION

Some years ago a model of the broadband, double-ridged pyramidal horn described by Kerr [1] was manufactured at NIAST for use as a broadband source antenna in the anechoic chamber. The measured patterns and gain of this antenna could not be correlated with those of conventional pyramidal horns. It appeared that the exponential ridges used for broadband impedance matching had a major influence on the antenna patterns. Following a suggestion made earlier [2], the four walls of Kerr's antenna were removed leaving only the double-ridged waveguide launcher and the exponential ridges.

The antenna then became a gradually diverging two-conductor balanced transmission line. A line of this type acts as a broadband radiator when the separation between the conductors is several wavelengths [3].

In the absence of the four sidewalls, the exponential ridged antenna has a very low profile. This paper presents the results of an attempt to further reduce the size of the antenna by truncating the ridge extensions so that the separation between them is only a fraction of a wavelength at the lowest usable frequency. Although acceptable performance was readily achieved at the high-frequency end, the low-frequency performance of the truncated antenna was severely degraded when compared with that of the larger antenna. Specifically, it appeared that reflections from the tips of the ridge extensions caused poor VSWR performance and high back radiation. These problems were overcome by a combination of aperture matching [4], [5] and the use of microwave absorber.

DESCRIPTION

The dashed curve in Fig 1 shows the dimensions of the exponential ridges of the horn originally made for the anechoic chamber. With the origin at the end of the double-ridged waveguide section, the ridge extensions were constructed according to the expression $y = \pm 0,9 \exp(0,031\, x)$ millimetres (the exponential growth factor is the same as in [1] but the additional linear taper described there was not used). The ridge extensions were 140 mm long giving a 138 mm aperture which is more than a wavelength at 3 GHz.

The compact antenna (solid lines in Fig 1) consists of a 50 Ω coax-to-double-ridged-waveguide transition see [6] which is used to launch the wave on the exponential ridges. In this case the ridge extensions were constructed according to the expression $y = \pm 0,9 \exp(0,042\, x)$ millimetres. The ridge extensions are 66 mm long (yielding an aperture of about 29 mm) and 9 mm wide. The ends of the ridge extensions are terminated by cylinders 24 mm in diameter and 9 mm wide. The cylinders blend smoothly with the curvature of the ridges. The cylinders should be about a wavelength in diameter at the lowest frequency for optimum aperture matching [4]. At 3 GHz this would require 100 mm cylinders which are larger than the whole antenna. The authors have found experimentally that cylinders only a fraction of a wavelength in diameter at the lowest frequency give significant improvement in performance. To reduce back radiation and improve the general shape of the patterns, the outside edges of the ridges were covered with strips of absorbing material (e.g. ECCOSORB MF117) 9 mm wide.

MEASURED PERFORMANCE

Reflection Coefficient (VSWR)

Fig 2 shows the reflection coefficient (VSWR) of the compact antenna. For the unmatched aperture (i.e. no cylindrical termination or absorber) the VSWR is better than 2:1 from about 5 GHz up; for the matched aperture (see Fig 1) the VSWR is better than 2:1 from about 3 GHz up and is better than 1,5:1 from 3,5 to 9,5 GHz. This represents a significant improvement for the matched aperture over the unmatched aperture. The major improvement in VSWR is made by the cylindrical terminations, however, the absorber strips do contribute to the improved VSWR at the low-frequency end.

Radiation Characteristics

The effects of aperture matching are most dramatic at the low-frequency end. Fig 3 shows the H-plane pattern for the following cases:

(a) unmatched aperture,

(b) cylindrical terminations only and

(c) cylindrical terminations plus absorber strips.

The most obvious feature of the patterns is that the gain of the compact antenna with the matched aperture has increased by about 5 dB over that of the unmatched aperture.

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An increase in gain is not unexpected since the cylinders have effectively increased the aperture size. The absorber strips have minimal effect on the peak gain; this is true throughout the frequency range.

For the unmatched aperture the front-to-back (F/B) ratio is about 4 dB, the addition of the cylinders improves this by 2 dB to about 6 dB. The absorber strips give a dramatic improvement of a further 6 dB giving an overall F/B ratio at 3 GHz of about 12 dB. A swept-frequency technique [7] was used to examine the F/B ratio as a function of frequency for the various terminations (see Fig 4). For the unmatched compact antenna the F/B ratio is less than 10 dB below about 6 GHz. For the fully aperture-matched antenna the F/B ratio is better than 10 dB over the entire frequency range from 2 to 11 GHz. In the absence of the absorber strips the F/B ratio shows two sharp peaks of about 30 dB at 5,5 and 11 GHz. These peaks are caused by the interaction between the rays which creep around the cylinders and shed tangentially to the 180° position and other rays which creep further around the cylinders, are reflected and propagate along the outer surfaces of the ridge extensions. When the absorber strips are added the rays travelling along the ridges are attenuated and only the rays which shed tangentially to 180° contribute to the back radiation.

Measured E- and H-plane patterns at 3, 7 and 11 GHz are shown in Fig 5. The patterns are extremely symmetrical about the antenna axis and for this reason half of the E-plane patterns are shown on the left-hand side and half the H-plane patterns are shown on the right-hand side of the composite figure. The absorber strips play a major role in maintaining well behaved F/B ratios (see Fig 4) and contribute significantly to reducing the sidelobes in the rear hemisphere of the antenna.

Gain

The gain of the compact, aperture-matched antenna is compared with that of the unmatched antenna in Fig 6. The gain of the latter antenna is significantly lower than that of the aperture-matched antenna, particularly at frequencies below 4 GHz. For comparison the gain of the original large aperture antenna is also shown. The gain of this antenna rises quite rapidly and then stays constant at about 11 dBi.

CONCLUSIONS

A novel technique for reducing the length of a balanced transmission line antenna, while maintaining acceptable performance has been introduced. The VSWR and F/B ratio of the compact antenna were improved by a combination of aperture matching and the use of microwave absorber strips. The compact antenna has good electrical performance from 3 to 11 GHz.
A brief experiment has been conducted to examine the properties of the compact antenna shown in Fig 1 in the 11 to 18 GHz region. It was found that the gain remained almost constant at 11 dBi and the 3 dB beamwidth (E- and H-plane) remained nearly constant at 45°. The high-frequency performance of the compact, aperture-matched antenna described in this paper can be extended to 18 GHz by a re-design of the launcher to extend its upper cut off to beyond 18 GHz.

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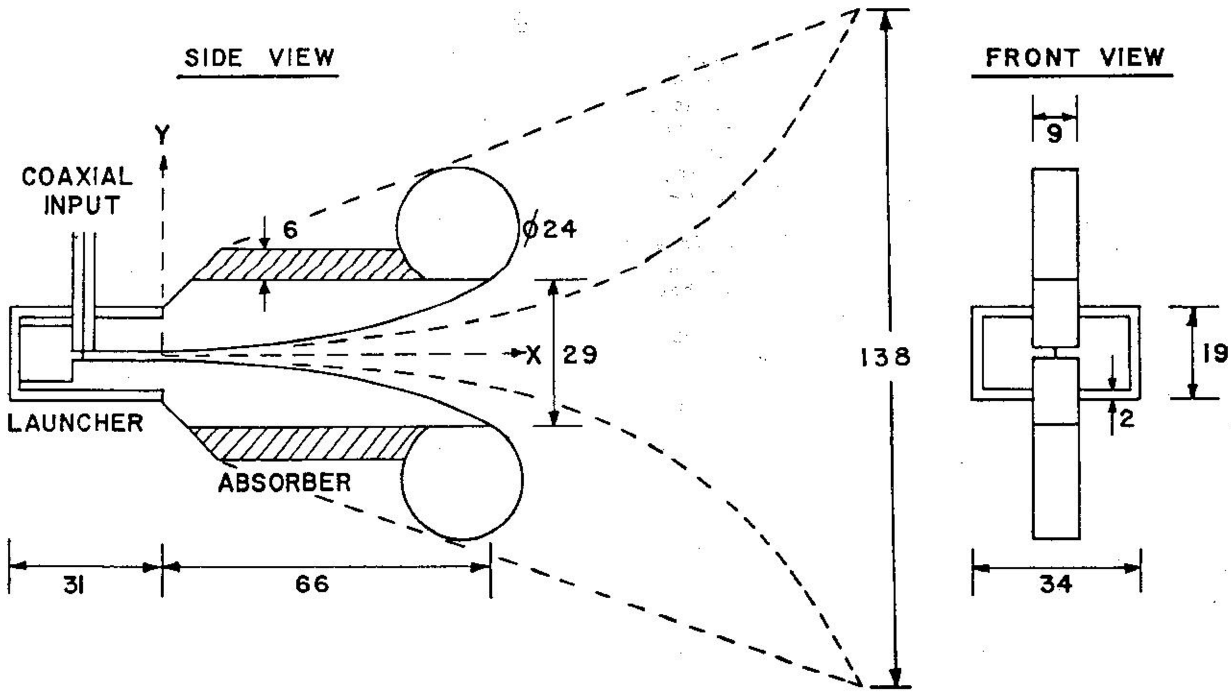

Fig 1 A compact, aperture-matched antenna (the dashed curve shows the 138 mm aperture antenna)

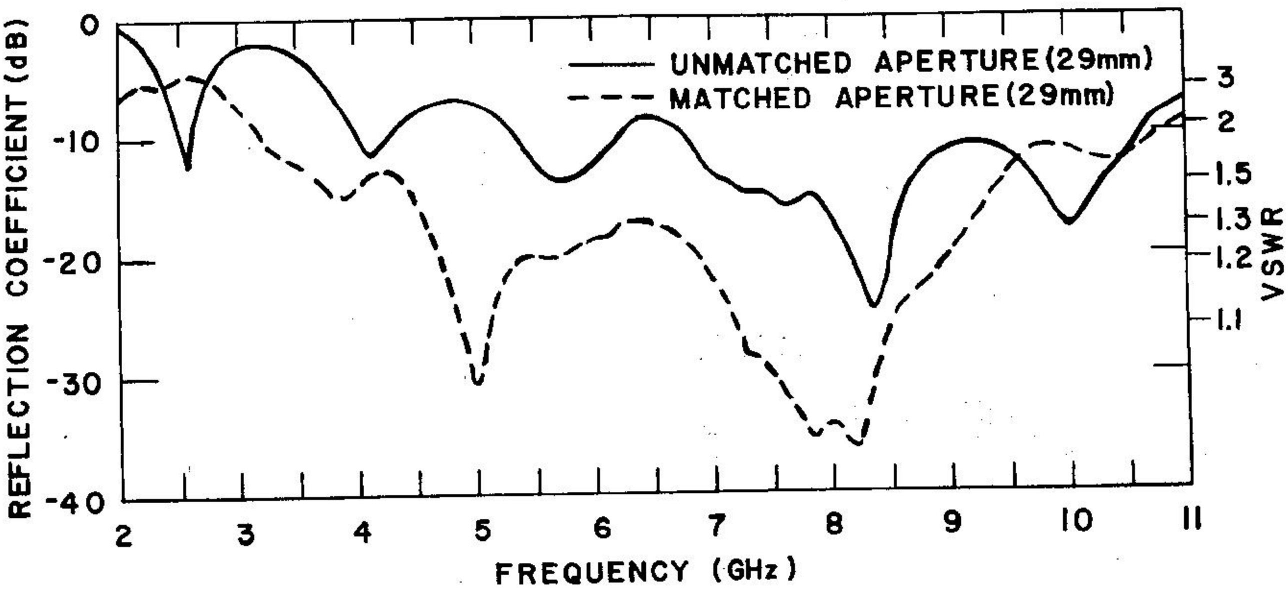

Fig 2 : Measured reflection coefficient of compact antenna with and without aperture matching

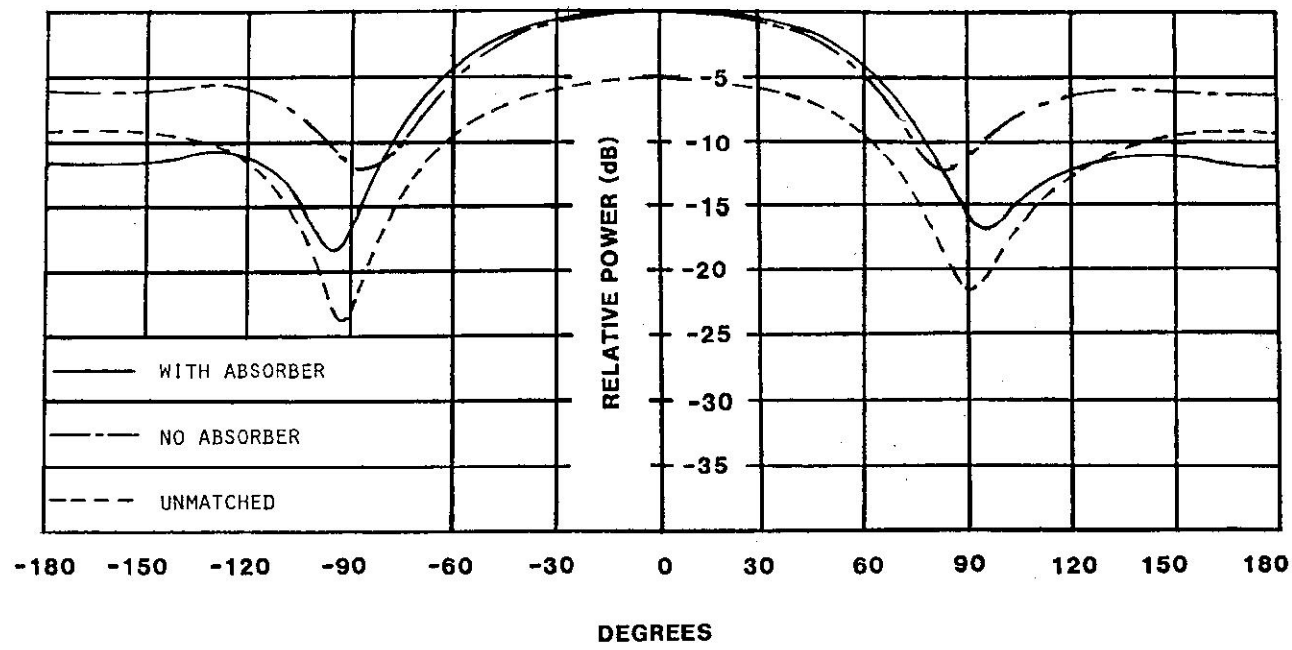

Fig 3 H-plane patterns at 3 GHz for various forms of aperture matching

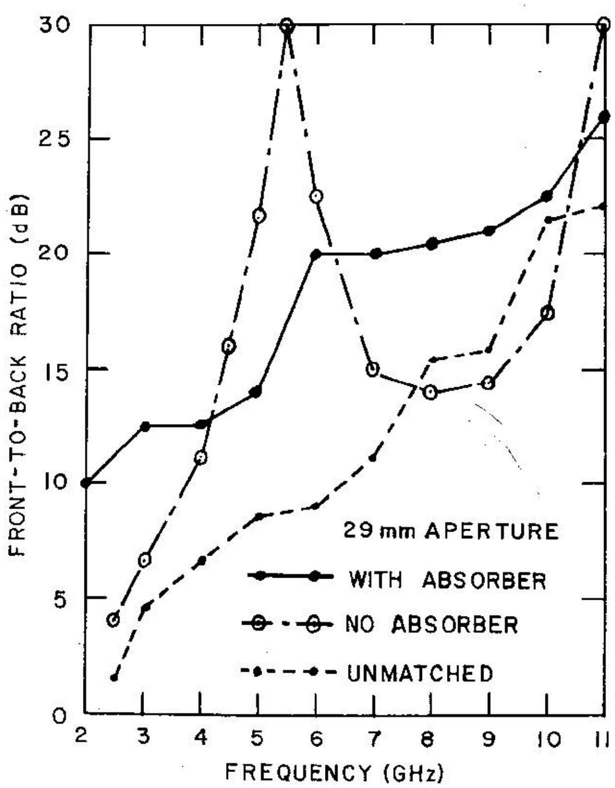

Fig 4 Front-to-back ratio for various terminations (data taken from swept-frequency measurements)

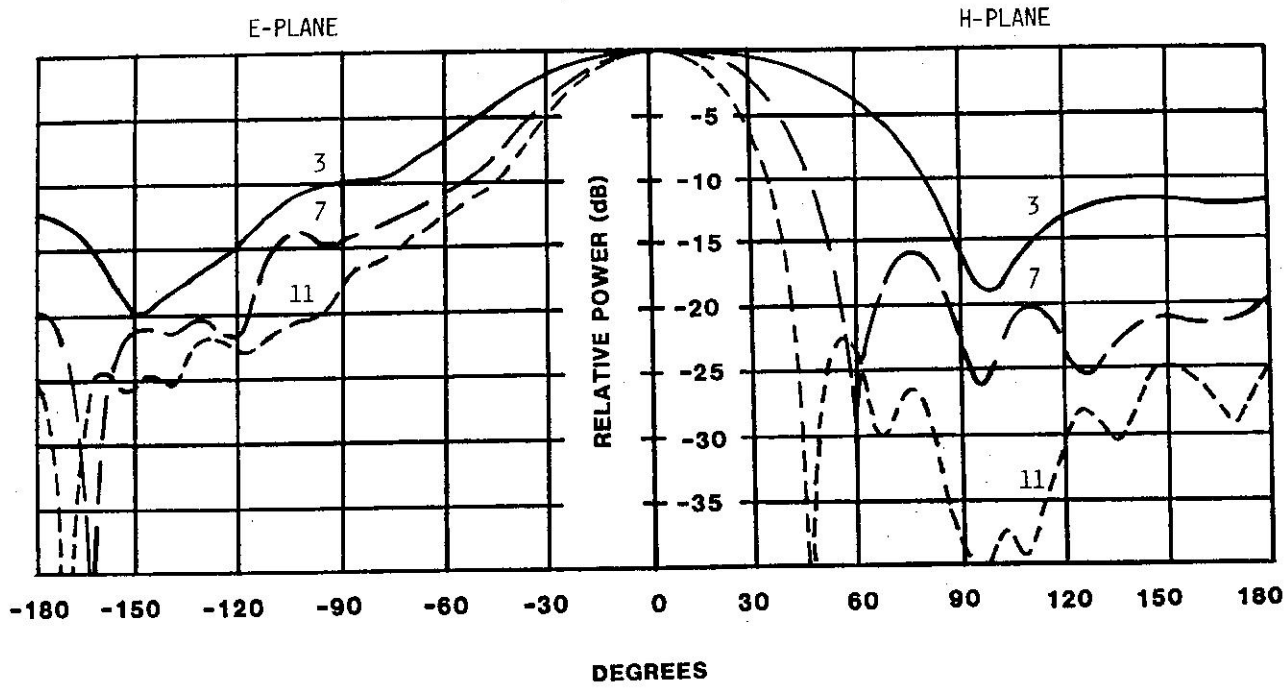

Fig 5 Measured E- and H-plane patterns at 3, 7 and 11 GHz

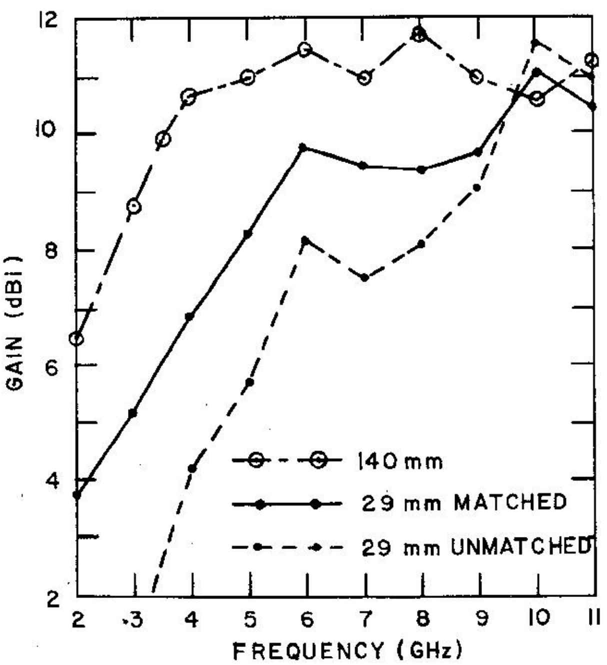

Fig 6 Gain of compact antenna with and without aperture matching compared to gain of 140 mm aperture antenna