ASSIGNMENT 6 MICROWAVE TUNER

CONTENT

The need to match a load to its source is introduced and the use of a slotted-line tuner is investigated.

EQUIPMENT REQUIRED

Qty	Ident. letter	Description
1	–	Control Console
1	A	Variable Attenuator
1	B	Slotted–line
1	C	Slotted–line Tuner
1	P	X–Band Oscillator
1	R	Short–circuit Terminator
1	S	Probe Detector Assembly

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OBJECTIVES

When you have completed this assignment you will:

- Be aware of the need for tuning of a mismatched load.
- Be familiar with the concept of admittance in a waveguide.
- Know how to use a slotted–line tuner to achieve a match between a load and source.

KNOWLEDGE LEVEL

Before you start this assignment you should:

- Have completed Assignment 5 'Measurement of Impedance'

Fig 6.1

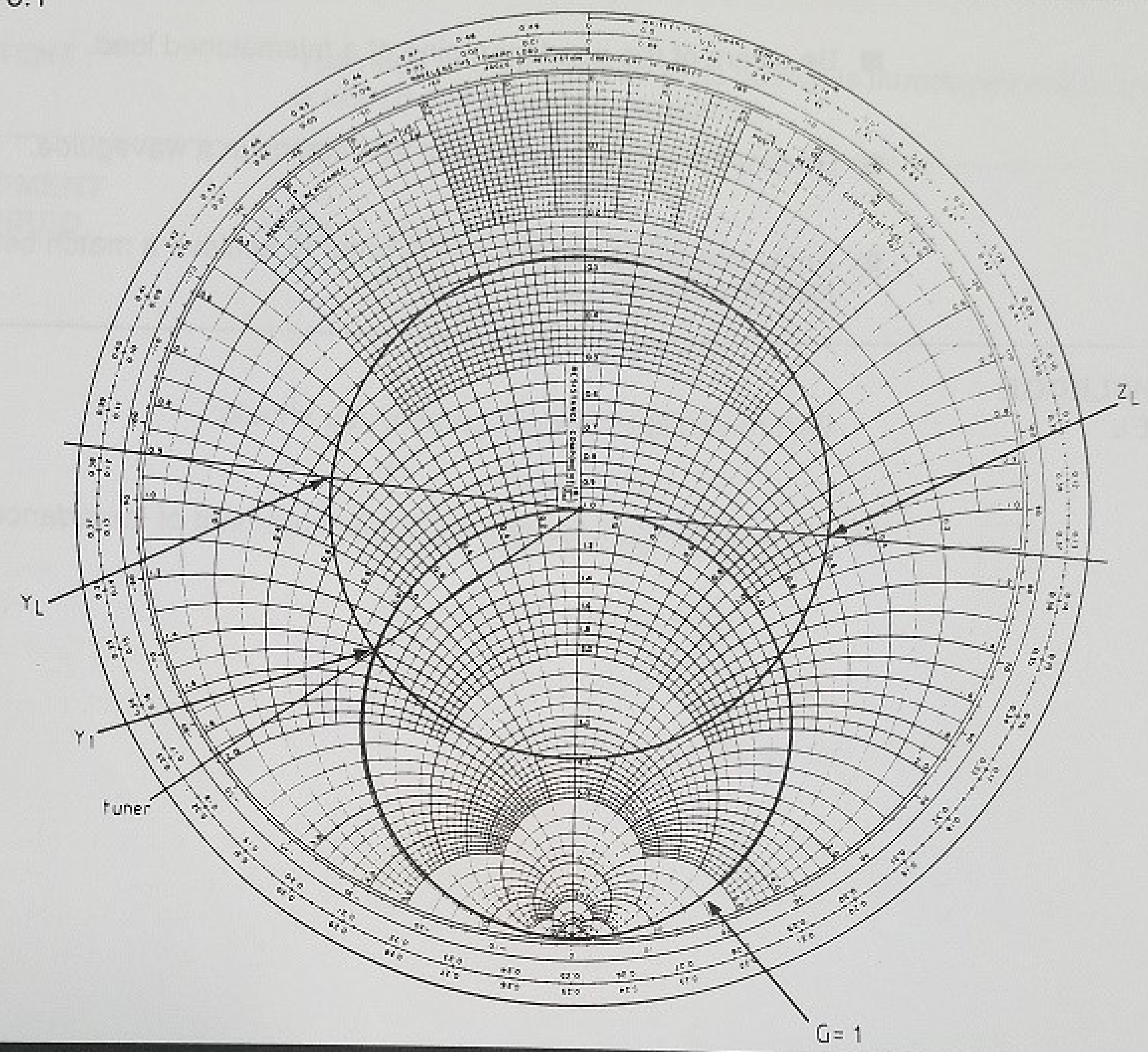


Fig 6.2

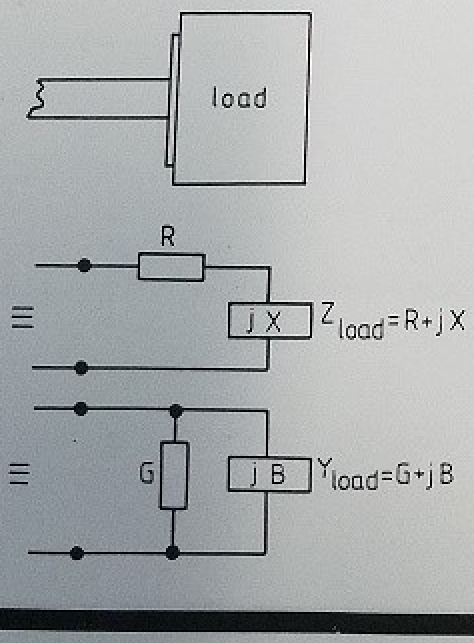


Fig 6.3

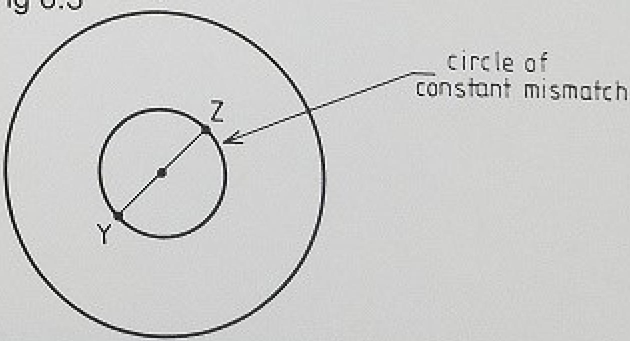
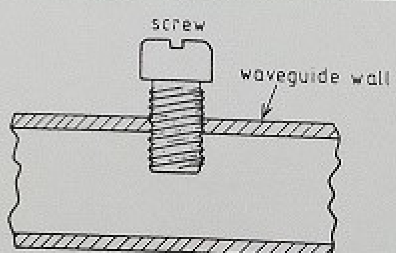


Fig 6.4



Capacitive Screw Mounted in a Waveguide

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INTRODUCTION

When microwave power is being sent to a load, reflected energy is usually lost and standing waves are formed. Systems which have large standing waves in them, are much more difficult to handle and adjust than 'flat' systems (having no standing waves). Furthermore, they are much more liable to wide variations in performance when the conditions are disturbed, e.g by temperature or other ambient changes, or drift of the signal frequency.

There are therefore several reasons for wanting a load to accept all the r.f energy incident on it, without reflection. To illustrate this (ref. fig 6.2), suppose we have a waveguide terminated in a load which is mismatched.

We could say that the load has a normalised impedance $\frac{(R+jX)}{Z_0}$,
but it is more convenient to think of its 'admittance', which is simply the reciprocal of impedance. So let the load admittance be $Y_L = G_L + jB_L$. In a similar way the waveguide can be said to have a characteristic admittance Y_0, which is simply the reciprocal of the characteristic impedance Z_0, and the normalised admittance is $\frac{Y}{Y_0}$

A convenient feature of a Smith chart is that if the normalised impedance is represented by one point, Z, on a constant-mismatch circle, then the normalised admittance Y is found simply moving to the other end of the diameter through Z, (see fig 6.3). This demonstrates the relationship between Z, a normalized impedance, and $Y = \frac{1}{Z}$ a normalized admittance.

If we move along the waveguide, back toward the oscillator, the admittance Y= G+ jB will change, through values represented by the circle of constant mismatch in a Smith chart (see fig 6.1). A point Y_1 can be found where the conductance G becomes equal to Y_0. In general the '*susceptance*' jB will be non-zero. If we could put in parallel with Y at this point a susceptance –jB, the combined susceptance would be zero, and Y would simply become Y_0. A match would be thus be achieved, in the sense that no part of an incident wave arriving at Y_1 would be reflected. All the energy of the wave must therefore go to the load.

A convenient form of susceptance which can be connected in the waveguide line is a capacitive screw, (fig 6.4).

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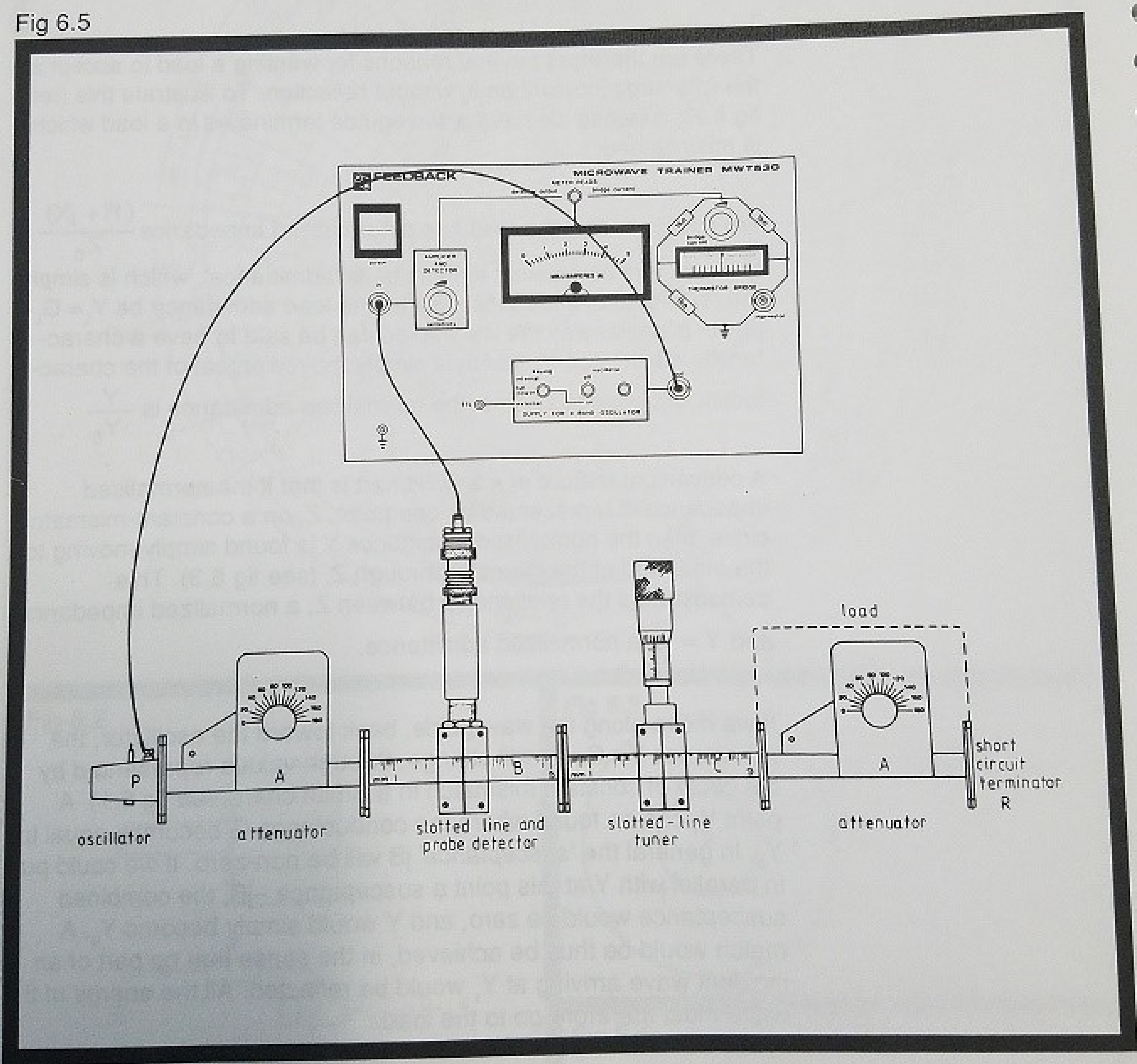
This of course can only provide a capacitive (positive-valued) susceptance. What if the jB which is to be cancelled is also capacitive? A moment's study of fig 6.1 will show that there is not just one point Y_1 where $G = Z_0$, but two. And the susceptance will be of opposite sign at the two points, so that one can always choose whichever kind is easier to cancel.

Fig 6.5



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EXPERIMENTAL PROCEDURE

Connect the equipment as shown in fig 6.5. On the Control Console, switch on the supply to the oscillator and set its left-hand switch for internal keying; set the METER READS switch to 'detector output'.

REMEMBER

NEVER look into an energised waveguide

Unscrew the Slotted-line Tuner as far as it will go (without undue force).

Move the Slotted-line Detector to find a maximum in the standing wave pattern. Adjust the source Attenuator until the meter reads about four-fifths full scale.

Find a minimum in the pattern and adjust the load Attenuator until the meter reads about one-tenth full scale. (It may be necessary to track the minimum position as it is disturbed by the Attenuator adjustment).

Use the Slotted-line Detector in the same way as in Assignment 5 to determine the impedance of the load there represented by the combination of the Tuner and Terminator. Write down the result and the intermediate results as in fig 6.6.

On a Smith chart, draw the constant-mismatch circle for this VSWR and the circle G = 1.

Choose their point of intersection (Y1) having negative susceptance, see fig 6.1.

Fig 6.6

minimum position:

initial conditions $x_1 =$

with short-circuit representing load $x_2 =$

and $x_3 =$

$\lambda_g = 2(x_2 - x_3) =$

$\frac{(x_1 - x_2)}{\lambda_g} =$

From the Smith chart, normalised $Z_L =$

Y_L (opposite end of diameter) =

Find the distance from the load at which it occurs. This is given (in wavelengths) by the distance along the outer scale from Y_L to Y_1, in the direction 'towards generator'. If necessary add one or more half-wavelengths to that distance (since the impedance pattern repeats every half wavelength). Record the position chosen.

Position the screw of the Tuner at a position along its slotted guide in accordance with your calculated position

ie (distance in λ) x (λ_g in mm).

It is then necessary to adjust the depth of penetration of the screw and make a fine adjustment to the slide position, to reduce the VSWR as much as possible. Do these two adjustments in sequence, as follows:

1 Make sure that the Detector is accurately at a minimum.

2 Adjust the Tuner's screw penetration to raise the meter reading and carefully try a small adjustment of its longitudinal position to raise the reading further.

3 By moving the Detector along the pattern, check that the adjustments have reduced the VSWR.

4 Repeat the sequence until further improvement becomes difficult.

Measure and record the final value of VSWR. Record the final position of the Slotted-line Tuner and compare it with that predicted from your impedance measurements.

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SUMMARY

A tuner is a device which, used in conjunction with a mismatched load, presents a matched composite load to the source.

For matching at a single frequency, it suffices to find a point in the transmission path where the admittance has a real component (conductance) equal to the characteristic admittance, and to cancel out its reactive component by adding a parallel reactance of opposite sign.

Typically the added reactance is a screw probe adding parallel capacitance to the transmission path.

Alternative Tuning Methods

In principle matching could be achieved by adding reactance of either sign, either in parallel or in series with the waveguide path, in suitable positions. Where a series component (usually inductive) is added, the analysis would more conveniently be based on impedances rather than admittances.

Chapter 3 Assignment 6 - Typical Results and Answers

As instructed, the VSWR should be about $\sqrt{\frac{4}{0.5}} = 2.83$

Other details of the results may vary, as they will depend on the attenuator characteristics, which are not closely controlled.

Typical results, with reference to the Smith chart opposite, follow.

minimum position:

initial conditions $x_1 = 39.8\text{mm}$

with short-circuit representing load $x_2 = 35.5\text{mm}$

and $x_3 = 17.5\text{mm}$

18.0mm

$$\lambda_g = 2(x_2 - x_3) = 36.0\text{mm}$$

$$\frac{(x_1 - x_2)}{\lambda_g} = \frac{(39.8 - 35.5)}{36} = 0.119\lambda$$

From the Smith chart, normalised $Z_L = 0.60 + j0.73$

Y_L (opposite end of diameter) $= 0.67 + j0.84$

The position of the Smith chart, fig E.6, corresponding to Y_L on the 'toward generator' scale is 0.369λ.

The constant mismatch circle for VSWR = 2.83 meets the circle G = 1 at 1, ±j1.1, so the tuner requires to be set at the point corresponding to 1,–j1.1, for which the 'toward generator' scale reading is 0.335.The tuner therefore requires to be set at a distance from the load equal to (0.335–0.369)λ = –0.034λ (plus any integral number of half–wavelengths). A convenient distance is

(1–0.034) x 36 = 34.8mm for practical purposes.

Chapter 3 — Assignment 6 - Typical Results and Answers

In practice the prediction is unlikely to be perfect, but the experiment which gave these results produced a VSWR of 1.2 when the Tuner probe depth was suitably set at a distance of 38mm from the plane (and finding the correct distance was greatly eased by having a prediction accuracy within 11% of the half–wavelength).

Fig E.6