port 1. $S_{11} = OO'$ is located on the Smith chart where O' is the 'iconocentre'.

2. Placing a sliding short at port 2, $\theta_2 = \beta l_2$ is varied to obtain Γ_1 circle on the Smith chart. The centre C is determined on the diagram.
3. Placing open circuit at the reference plane of port 2 ($\theta_2 = \pi/2$, $l_2 = \lambda_g/4$) the corresponding $\Gamma_1 = \Gamma_1'$ is noted and indicated on Γ_1 circle as P'.

Construction of Deschamp's circle is done in the following manner A straight line is drawn from P' to a point Q on the circle through O' and another line from Q to a point P'' on the circle through C. The angle of the phase or CP'' is equal to $2\theta_{12}$, where θ_{12} = angle of S_{12}.

Now

$$O'C = OC - OO' = S_{12}^2 S_{22}^* / (1 - |S_{22}|^2) \tag{13.124}$$

Therefore, angle of $O'C = 2\theta_{12} - \theta_{22}$. Since angle of $CP'' = 2\theta_{12}$ = Angle BCQ, therefore, angle of CP''-angle of $O'C = \theta_{22}$ = Angle $P''CO'$.

Therefore,

$$|S_{11}| = OO', \theta_{11} = \text{angle of } NOO' \tag{13.125}$$

and

$$\left|S_{22}^*\right| = O'C/CP'', \theta_{22} = \text{angle } P''CO' \tag{13.126}$$

$$|S_{12}| = \sqrt{\left[\text{Radius of the circle} \times \left(1 - |S_{22}|^2\right)\right]} \tag{13.127}$$

$$\theta_{12} = \text{angle } BCQ/2 \tag{13.128}$$

A similar procedure is followed for other ports.

Ordinarily magic-T is not a matched one because of discontinuity presents at the junction. Hence H-arm is matched by a tuning screw from the bottom wall and E-arm is matched by an inductive iris by trial and error method. With this arrangement other two arms are automatically matched.

13.16 MICROWAVE ANTENNA MEASUREMENTS

The most important parameters required to be measured to determine the performance characteristics of microwave antennas are radiation amplitude patterns, radiation phase patterns, absolute gain, directivity, radiation efficiency, beamwidth, input impedance, bandwidth and polarisations. The accurate measurement methods for these parameters require standard antenna test ranges.

13.16.1 Antenna Test Ranges

There are two basic antenna test ranges used for antenna measurements. These are indoor and outdoor test ranges. Usual indoor test range is an anechoic chamber which consists of a rectangular volume enclosed by microwave absorber walls. These walls reduce reflections from the boundary walls and increases the measurement accuracy. Microwave absorbers are carbon impregnated polyurathene foam in the shape of pyramids. The materials are expensive for lower frequency ranges because the typical the size of pyramid is nearly 5'–6' for 100 MHz. Most of the antenna parameters to be measured require uniform plane wave field incidence on the test antenna placed at a far field distance from a transmitting antenna. Consequently the requirement of a large space limits the use of the costly indoor facility. Special indoor ranges such as compact range and near field range could be used where the former produces a plane wave field in a smaller distance by means of an offset fed reflector antenna having a special edge geometry. The latter one uses mathematical computations of the near field measurement data to obtain the far field information. Both these methods are very costly and have several limitations. In this section, far field outdoor test range is discussed for antenna parameter measurements.

Outdoor antenna test range The most popular microwave antenna test range is the free space outdoor range in which the antennas are mounted on tall towers as shown in Fig.13.39. The reflections from the surrounding environment are reduced by

1. Selecting the directivity and side lobe level of the transmitting antenna.
2. Making line-of-sight between the antennas obstacle free.
3. Absorbing or redirecting the energy that is reflected from the range surface or from any obstacle.

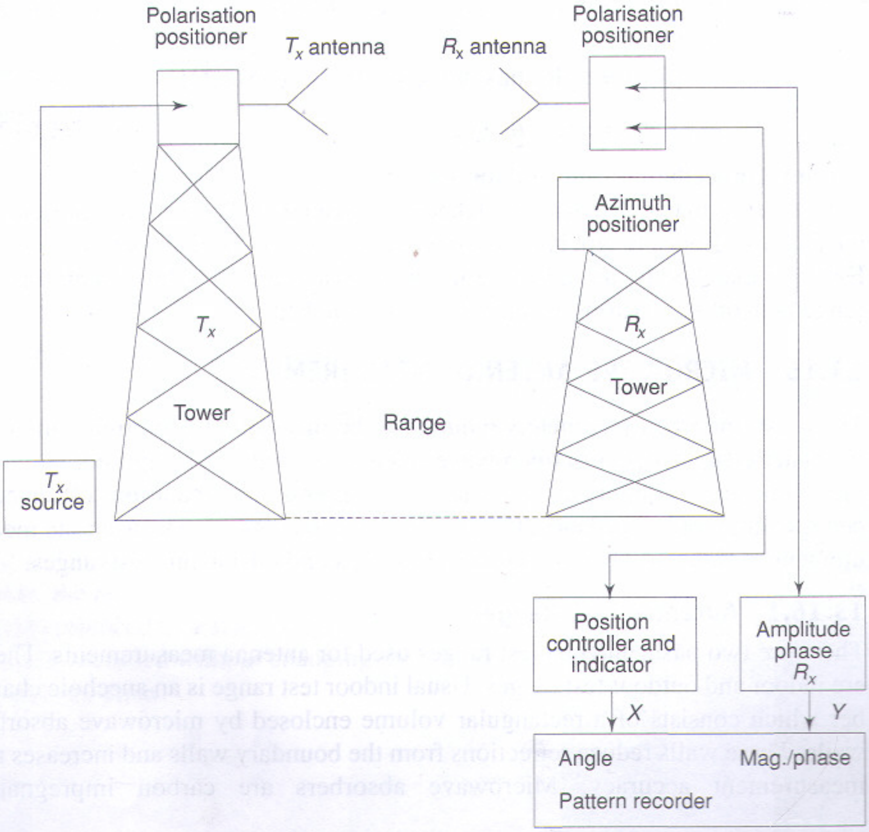

Fig. 13.39 *Outdoor antenna test range*

13.16.2 Radiation Pattern Measurements

The radiation pattern is a representation of the radiation characteristics of the antenna as a function of elevation angle θ and azimuthal angle ϕ for a constant radial distance and frequency. The three-dimensional pattern is decomposed into two orthogonal two-dimensional patterns in **E** and **H** field planes where the Z-axis is the line joining the transmitting and receiving antennas and perpendicular to the radiating apertures. Due to the reciprocal characteristics of antennas, the measurements are performed with the test antenna placed in the receiving mode. The source antenna is fed by a stable source and the received signal is measured using a receiver. The output of the receiver is fed to Y-axis input of an XY recorder. The receiving antenna positioner controller plane and the angle information is fed to X-axis input of the XY recorder. Thus the amplitude vs angle plot is obtained from the recorder output.

Initially two antennas are aligned in the line of their maximum radiation direction by adjusting the angle and height by the controller and antenna mast. Effects of all surroundings are removed or suppressed through increased directivity and low side lobes of the source antenna, clearance of LOS, and absorption of energy reaching the range surface.

The following precautions are taken for better accuracy in the measurements:

1. Effects of coupling between antennas—inductive or capacitive—causes error in measurement. The former exists at lower microwave frequencies and negligible if range $R \geq 10\ \lambda$. Mutual coupling due to scattering and reradiation of energy by test and source antenna causes error in measurement.
2. Effect of curvature of the incident phase front produces phase variation over the aperture of test antenna and this restricts the range R. For a phase deviation at the edge $\leq \pi/8$ radians, $R \leq 2D^2/\lambda$, where D is the maximum size of the aperture.
3. Effect of amplitude taper over the test aperture will give deviation of the measured pattern from the actual. This occurs if the illuminating field is not constant over the region of the test aperture. Tolerable limit of amplitude taper is 0.25 dB, for which decrease in gain is 0.1 dB.
4. Interference from spurious radiating sources should be avoided.

13.16.3 Phase Measurement

The phase of the radiated field is a relative quantity and is measured with respect to a reference as shown in Fig.13.40. This reference is provided either by coupling a fraction of the transmitted signal to the reference channel of the receiver or by receiving the transmitted signal with a fixed antenna placed near the test antenna. The fixed antenna output is fed to the reference channel of the receiver and the phase pattern is recorded as the antenna under test is rotated in the horizontal plane.

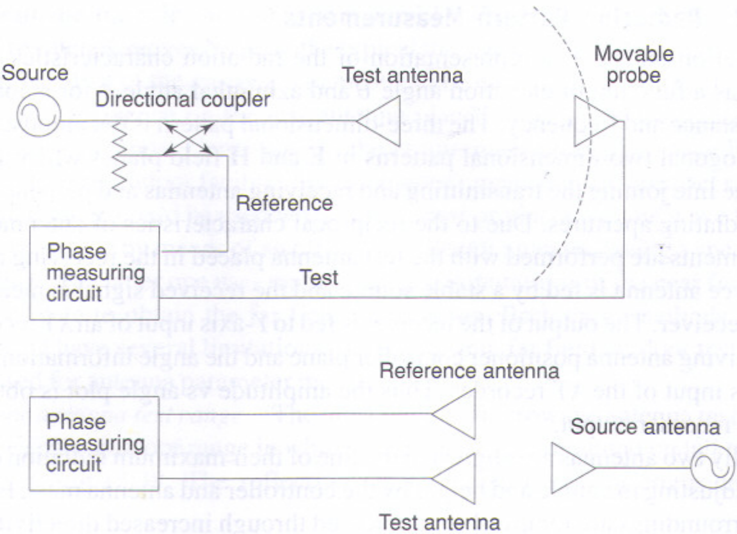

Fig. 13.40 *Phase pattern measurement set-up*

13.16.4 Phase Centre Measurement

When an antenna radiates, there is an equivalent point in the antenna geometry which represents the radiation centre. At the far field region the phase pattern of this antenna remains constant with angle when measured with respect to this point. Therefore, the phase centre of the test antenna is determined by positioning the rotational axis of the test antenna mast such that the phase pattern within the main beam remains constant.

13.16.5 Beamwidth

The beamwidth of the antenna is calculated from the angle subtended by the 3 dB or 10 dB points on the both sides of radiation maximum in the main beam.

13.16.6 Gain Measurements

The gain is the most important parameter to be measured for microwave antennas because it is used directly in the link calculations. There are three basic methods that can be used to measure the gain: standard antenna method, two antenna method and three antenna method.

Standard antenna method This method uses two sets of measurements with the test and standard gain antennas. Using the test antenna of gain G_r in receiving mode, the received power P_r is recorded in a matched recorder. The test antenna is then replaced by a standard gain antenna of gain G_s and the received power P_s is again recorded without changing the transmitted power and geometrical configuration. Then

$$\frac{P_r}{P_s} = \frac{G_r}{G_s}$$