INTRODUCTION

A slot on the wall of a waveguide serves both as a coupler and a radiating element. By using waveguide-fed slot in an antenna array the amplitude and phase of radiation can be controlled electronically by means of ferrite discontinuities , thus combining the radiating element and the phase shifter into a single element[1]. It is also possible to vary the magnitude and phase of excitation by displacing an inclined broad wall slot[2]. A slot is also capable of giving vertical or horizontal polarisation depending on its location and orientation in the broadwall or narrow wall of a waveguide. Because of these interesting characteristics, the waveguide-fed slot has found an important place in the array antennas as a radiating element. Array antennas have been employed to determine the coordinates of very fast moving targets and also to perform a number of simultaneous functions including tracking of many targets[3,4]. The most simple and relatively inexpensive form of radar is the one using waveguide slot arrays[5,6] Slots milled either on the broad or narrow wall of a rectangular waveguide can be used in antenna array for radars. This type of array has found wide applications in naval radars[7]. They have also been used in conformal arrays and the arrays with rotational symmetry[8]. Very high speed airborne vehicles and missiles use slot arrays as they provide little aerodynamic drag[9]. Attempts have been made to use slot array antennas in satellite for telemetry and communication[10]. Slot antennas have also been used to obtain circularly polarised radiation[11,12]. The compact feed and light weight are factors responsible for use of slot arrays on satellites and airborne vehicles for remote sensing application. Thus slot arrays have a wide field of application and therefore have been the subject of considerable theoretical and experimental investigations spanning over almost five decades[13-18].

Like any other antenna array, a waveguide fed slot array should have the following characteristics over the desired frequency band of operation :

a. minimum input voltage standing wave ratio (VSWR),
b. maximum insertion loss with minimum power dissipation in matched load,
c. maximum gain and radiation efficiency,
d. specified radiation pattern, and
e. low cross-polarization.

Analysis on performance of slot array requires accurate information of the variation of admittance of slots with frequency[19-21].

The investigations on the immittance properties of slots in the wall of a rectangular waveguide have been summarized by Silver[22] and Watson[18]. Till Oliner's work appeared, little information was available on the admittance properties of slots. The much referred work of Stevenson[17] for the determination of slot resistance/conductance is applicable to resonant slots only. Cullen[23] determined the admittance presented by a resonant shunt slot on the broad wall of a rectangular waveguide using transmission line theory and found the effect of small deviation from the resonance. Stegen[24] studied experimentally the variation of the conductance and susceptance of a slot in the waveguide wall with resonant length. The effect of wall thickness on the immittance characteristics of the slot was also investigated by Oliner. Larson and Power[25] presented a procedure to determine the impedance and resonant length of radiating slots cut on the wall of a rectangular waveguide filled with dielectric with simple modifications to Stevenson's and Oliner's formulae. Das and Sanyal[15] found a more generalised expression for the immittance of a broad wall slot radiator, valid over a wide range of slot lengths ($0.4\lambda - 1.5\lambda$).

In all the above investigations the variational formula for the impedance characteristics has been derived by using reaction concept and dyadic Green's function. The dyadic Green's function is quite complex and results in the expression for complex radiated power in the form of a quadruple integral[15,16] and requires many simplifying assumptions to evaluate the integral in a closed form. Rhodes[26,27] used the concept of plane wave spectrum introduced by Booker and Clemnow[28] and found the impedance of dipòle antenna excited by electric current, and showed that the evaluation of complex radiated power would get simplified if the expression is obtained in terms of angular spectrum of plane waves. Das and Sinha[29] found the immittance characteristics of longitudinal slots on the broad wall of a waveguide from a knowledge of the complex radiated power obtained from angular spectrum of plane waves and the discontinuities in modal voltage and current.

Due to the inherent advantage in machining, the inclined slots in the narrow wall of a waveguide are extensively used for the design of slot arrays. Stevenson[17], in his work, has derived a closed form expression for the conductance of inclined narrow wall slot with slot length equal to $\lambda/2$. Dodds et al.[30] have presented an incremental conductance curve obtained experimentally. The data obtainable from the curve can be used only for resonant slot array, and for slots having same inclination. Das et al.[31] have derived a general admittance of narrow wall inclined slot for arbitrary inclination, length and depth of cut from the knowledge of complex radiated power obtained from angular spectrum of plane waves and the discontinuities in modal voltage and current.

In an array consisting of either longitudinal broad wall slots or inclined narrow wall slots there is a progressive decay in the amplitude of excitation because of the radiation from successive slots in the array. The relationship between the attenuation and the admittance of individual slots is very important for the design of a slot array. Further, it is necessary to consider the effect of loss due to the finite conductivity of the waveguide walls particularly in the design of long slot arrays designed for application at high frequency.

The design of waveguide-fed slot array using displaced shunt slot in the broad wall and shunt inclined slots in the narrow wall was investigated by Fry[32]. He found the spacing and distribution of slots for a 10 cms long array. Cullen and Goward[33], discussed two methods of array design suggested by Stratton and Woodward ınd the experimental results were comparėd with the theory for two rrays. Watson[18] has considered both transverse and longitudinal polarisations, taking due care of mutual interactions between the nclined slots cut in the narrow face of a waveguide in a longitudinally polarised array. He has also reported investigation on a road band array of inclined slots in the broad face supporting the esults experimentally. Tricaud[34] found that the frequency bandwidth f a slot array can be made large by spacing the radiating slots at electrical lengths slightly different from half the guide wavelength. tegen and Reed[35] found that the pencil beams with controllable sidelobe level can be produced by using a large number of slots per wavelength and the mutual coupling effects can be kept small by aking the slot short compared to the wavelength. These arrays may thus be placed side by side without any interaction making it possible to have a two dimensional array. Dion[36] obtained the distribution of slot conductance of non-resonant arrays by considering the array as a continuous line source and determining the conductances for three sidelobe levels using Taylor[37] distribution. Earlier Taylor[37] solved the problem of synthesis of a line source optimizing beamwidth and sidelobe level. The continuous line source obtained in this way is equivalent to a discrete array consisting of adequate number of elements. Byers and Katchky[7] designed a slot array with very narrow beamwidth for marine radar.

Elliott[38-40] has done a good amount of work on the design of longitudinal shunt slot arrays for resonant and non-resonant slot spacings. He presented a generalised method of designing the waveguide-fed resonant slot array taking the effect of external mutual coupling[40]. Even though the method is optimum for designing small arrays it can also be used for designing long array. The design is based on iterative technique and requires a large amount of computer time. He has extended the above design for realising a non-resonant array which includes the effect of external mutual coupling. However, a good difference of 8 dB was reported between his experimental and theoretical sidelobe level[39].

The effect of radiation due to successive slots in a linear array on the gain and radiation pattern has been studied by Das[21] and also by Das and Sanyal[41]. The attenuation and gain were found by assuming the decay in amplitude of excitation to be representable by a single exponential form. In the design of optimum slot array by Das and Sanyal, a large deviation was found between the measured and theoretical values of attenuation. This is partly due to the fact that the formula for attenuation did not take into account the reflection occuring in between slots and due to the representation of the amplitude of excitation by a single exponential.

For the determination of radiation efficiency, gain and radiation pattern it is essential to find the variation of amplitude of excitation along the length of the slot array as a function of immittance of slots. Watson[18] derived the relationship between the variation in amplitude with slot conductance. The expression exhibits a large discrepancy between the theoretical and experimental results. Further, the expression does not take into account the reflection in between the slots and is, therefore, inaccurate