Microwave Imaging Probe using Bowtie Type of Optical Antenna Structure

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When a uniform plane electromagnetic wave is incident upon the small circular aperture in an infinite conducting plane, the transmitted power P_t through the aperture is very small. More specifically, the transmission cross section(TCS) T of the aperture whose diameter D is much smaller than the wavelength λ is proportional to $(D/\lambda)^4 \cdot D^2$ according to the Bethe's theory. Here the TCS T is defined so that the transmitted power P_t through the aperture may be given by the multiplication of the incident power density P_{inc} [W/m^2] and T [m^2], i.e., $P_t = P_{inc} T$.

It has been found that the TCS can be significantly enhanced by modifying the aperture shape as in the circular ridged aperture in the infinite thin conducting plane or by employing a transmission resonant cavity structure in a thick conducting plane. It is interesting to note that the TCS T for both the two structures can be increased to the maximum value of $T = 2G\lambda^2/4\pi$ [m^2] as a upper bound, where G means the gain of the aperture. This means that the incident power on the area corresponding to the T (usually much larger than the actual aperture area) is funneled into the actual aperture and transmitted through it and radiated into the opposite half space to incident side regardless of the actual aperture area under the transmission resonance where the transmitted power P_t becomes maximum i.e., $P_t = P_{inc} T$.

The near-field microscopy employs a probe of a subwavelength coupling hole(aperture) size and an object that is mounted in the near field of the probe, so that the spatial resolution is determined by the coupling hole size of the probe rather than the wavelength. Several designs of the microwave near-field probe have been used, such as circular aperture, rectangular aperture, and open waveguide. A smaller coupling circular aperture provides better resolution although this is not very practical because the transmitted power is very low as mentioned above. So several kinds of apertures such as long resonant slit and annular aperture have been studied to overcome such a low transmission efficiency problem. In general the transmission efficiency through a small coupling aperture and the spatial confinement of the electromagnetic energy are taken as two conflicting characteristics of the compromise problem which we should solve in the design procedure of near-field imaging probe. For this purpose, we consider the near-field imaging probe optical structure by incorporating a transmission resonant cavity in the rectangular waveguide run at the output.

Recently, as a near-field optical probe that combines spatial resolution well below diffraction limit with transmission efficiency approaching unity, a configuration was proposed in which a planar Bowtie antenna with an open-circuited gap at its apex is placed, for resonant transmission, half wavelength($\lambda/2$) in front of the open end of the rectangular waveguide. In the microwave regime, a Bowtie shaped antenna, where two triangles facing tip to tip are separated by a small gap, produces a large electric field confined to the area near the gap. For the transmission-resonant structure under consideration, the output coupling iris of the capacitive strip or Bowtie shaped antenna with an open-circuited gap at it's center or apex is employed whereas the input coupling iris is composed of a small hole in the transverse conducting wall.

We investigate the impedance matching property and spatial confinement of the electromagnetic energy for the proposed structure and compare with those for the recently reported optical antenna structure. It is shown that, a probe with desired transmission efficiency and spatial confinement of electromagnetic energy through the coupling aperture at the probe output can be synthesized by use of the transmission resonant cavity structure.