Quadrature Hybrid Design

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1 Introduction :

The primary aim of this report is to investigate the design of a Quadrature hybrid employing mostly standard sizes of Aluminium structural elements and extrusions; in other words, with practically no machining involved in the fabrication and yet achieving equivalent microwave characteristics of a fully–machined hybrid.
Selection of sub–assemblies will also be done in a similar fashion while computing their respective sizes.

2 Characteristic impedance of wire-impeded-in-trough line :

Trough lines will be the main element of this design with std. Al. sections and std. brass/Cu rods for the centre-line coaxial. As per Ref.[1], the characteristic impedance of a trough line geometry as shown in Fig.1 will be

$$Z_0 \;=\; 138\log\left(\frac{4D}{\pi d}\right)\cdot\tanh\left(\frac{\pi h}{D}\right) \tag{1}$$

The term $tanh\left(\frac{\pi h}{D}\right)$ charceterises the fringe–field effect as the relavant geometric quantities are involved. Since $\tanh(x) \simeq 1.0$ for $x \geq 4.0$. One can choose h such that $\tanh(\cdots)$ becomes unity.
If $\frac{h}{D} = 1.27$, then
$\tanh(\frac{\pi h}{D}) = \tanh(1.27\pi) = 0.9993.$
A safer choice for $\frac{h}{D} = 1.5$, so that $\tanh(1.5\pi) = 0.99984.$

Case(i):

Suppose $d = 5.5$ mm. (from Std. data of hard–drawn Brass or Cu. rod) and $D = 8.0$ mm.
Then for $\frac{h}{D} = 1.5$, h would be $1.5 \cdot 8.0 = 12.0$ mm.
The $Z_0 = 138\log\left(\frac{32}{5.5\pi}\right)\tanh(1.5\pi) \quad = 36.93\Omega$
So $D = 8.0$ mm. is not suitable, as 50 ohm line is preferred.

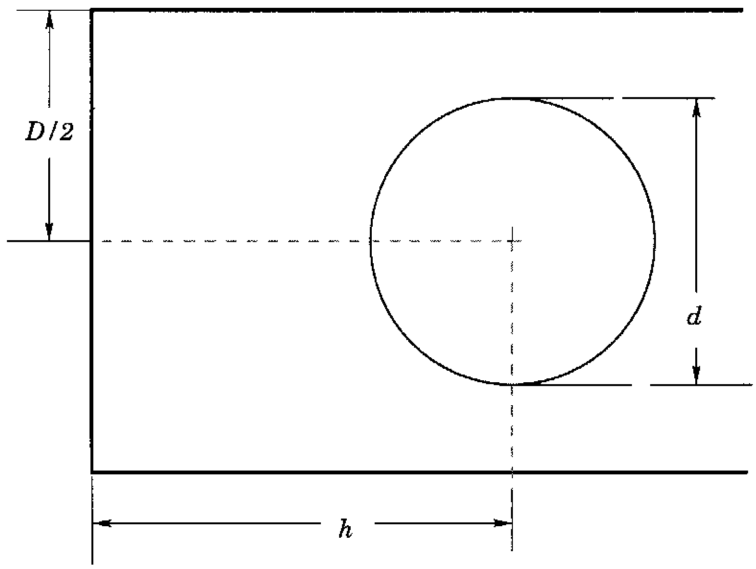


Fig. 1.

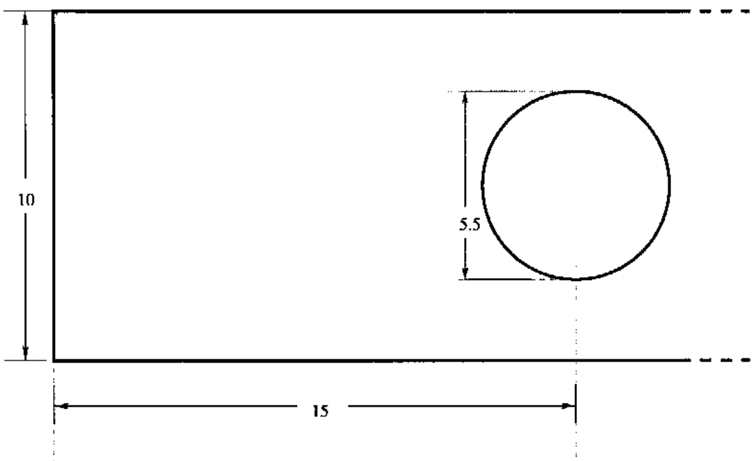
Case(ii):

Let D be equal to 10.0 mm.; then for $d = 5.5$ mm,
$Z_0 = 137.9779 \cdot \log\left(\frac{40}{5.5\pi}\right) \quad = 50.299\Omega$

So the configuration will be as shown in Fig.2. The 10 mm. spacing can be provided by a Al. square section of 10 x 10 mm. The top and bottom cover plates can be made of 3 mm. thick Al. sheet. Fig.3 shows some of the details of this design.

This part completes now only the design of the 50-Ω line part of the quadrature hybrid. For the $50/\sqrt{2}\,\Omega$ line, i.e. 35.4 Ω line, the computation proceed as follows :
For $D = 10$ mm., the Z_0 value for various standard rod diameters (of Brass/Cu.) are calculated first.
$d = 6.0$ mm ; $\quad Z_0 = 42.64\,\Omega$
$d = 8.0$ mm ; $\quad Z_0 = 27.85\,\Omega$
This implies that these std. rods cannot be used for the 10 mm.spacing. The solution is $d = 7.0$ mm., for which $Z_0 = 35.85\,\Omega$. The std. 8.0 mm. rod has to turned for 7.0 mm. dia. The configuration of the 35.4 Ω will be as shown in Fig.4.

Before embarking on the next design step, the primary aim of this design must be elaborated. If proved viable, this quad. hybrid will be part of the coaxial wave–guide feed at 610 MHz. In order to avoid losses at this frequency, coaxial cables of any-sort (not even semi–rigid ones) to connect various sub–assemblies (probe–to–balun,balun–to–quad.hybrid etc.) are to



All dimensions are in mm.

Fig. 2

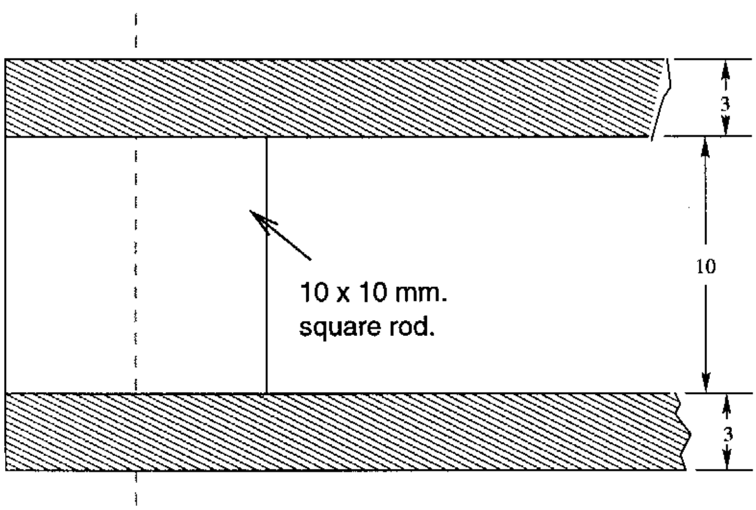


Fig. 3.

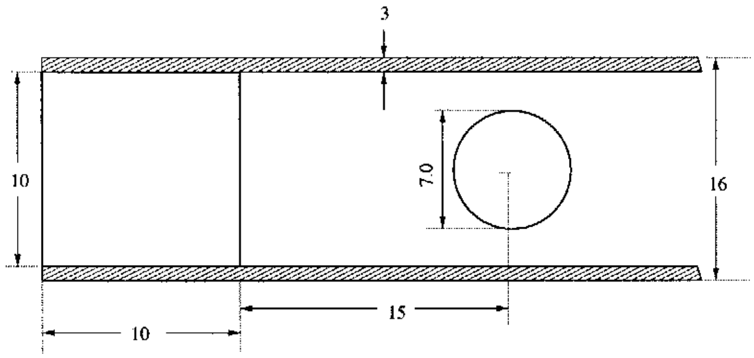


Fig. 4.

be avoided as much as possible.

To integrate the above designed– quad.hybrid with dipole–like balun output port (tentative only; needs further study and shown in Fig.5) the obvious choice is to fold–up the 50 Ω line. Fig.6 shows the lay–out of the complete quad. hybrid with the 50 and 35.4 Ω lines.

Fold–up of the 50– Ω line brings–in the additional constraint that the parallel arms should be well isolated, i.e., the mutual impedance between the arms should be as high as possible.

3 Mutual impedance between parallel wires, impeded in trough- enclosure :

As per Ref.[1], the characteristic impedance for the case shown in Fig.7 will be

$$Z_0 = 276 \log\left(\frac{4D}{\pi d}\right) \cdot \tanh\left(\frac{\pi s}{2D}\right) \tag{2}$$

For $D = 10$ mm., $d = 5.5$ mm. and presuming $s = 30$ mm., $Z_0 = 276 \log\left(\frac{4D}{5.5\pi}\right)\tanh(1.5\pi)$ $= 100.6\,\Omega$
For $s = 20$ mm., $Z_0 = 100.2\,\Omega$ and
For $s = 40$ mm., $Z_0 = 100.6\,\Omega$.
This reveals the fact that irrespective of the value s the Z_0 remains around 100 Ω only.

If d is reduced to 1 mm., then $Z_0 = 305\,\Omega$. So it is clear that for $d = 5.5$ and $D = 10$ mm, Z_0 value higher than 100 Ω cannot be achieved. Hence *the design envisaged in Fig.6 is impractical.*
To achieve the isolation, a better way would be to choose coaxial line from Port# 1 and Port# 2 to the junctions of 50 –Ω and 35.4 –Ω lines. The proposed feature will be as illustrated in

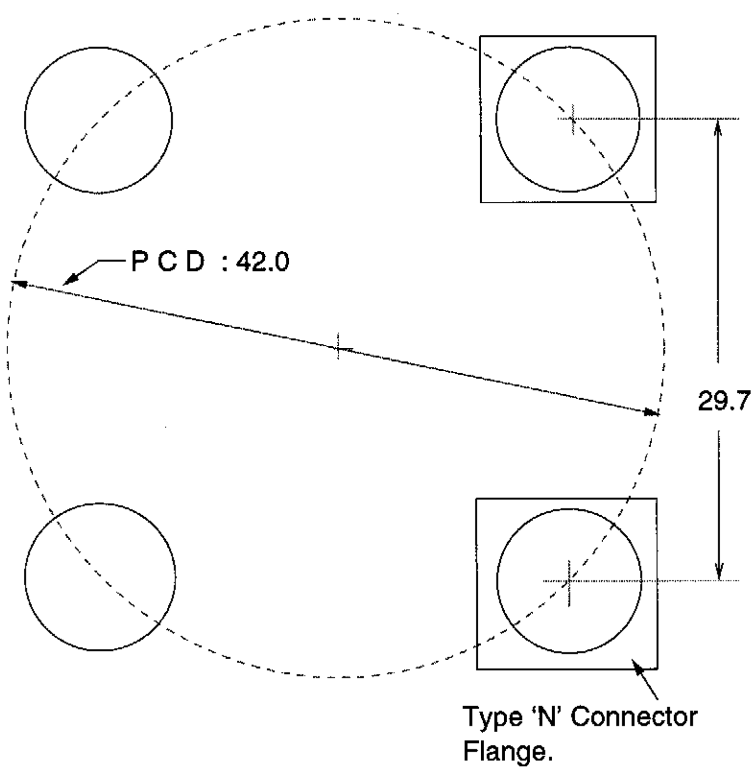


Fig. 5.

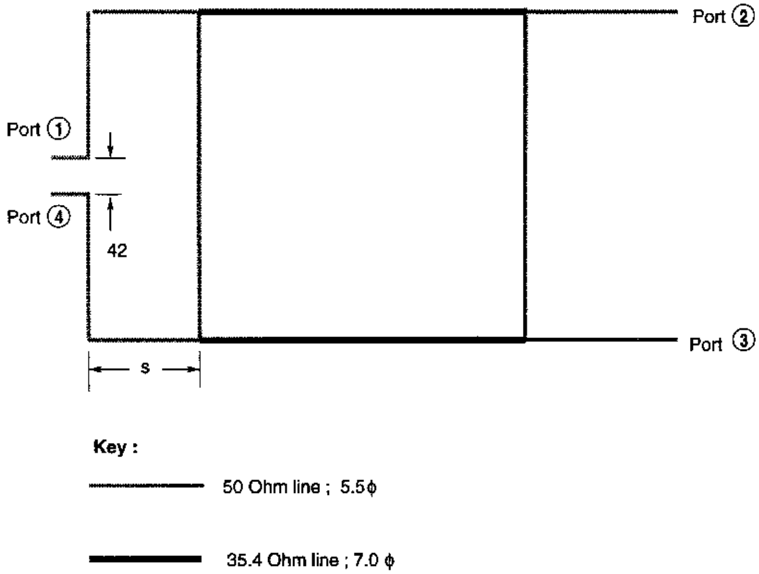

Port ②
Port ①
Port ④
42
Port ③
s
Key :
50 Ohm line ; 5.5ϕ
35.4 Ohm line ; 7.0 ϕ

Fig. 6.

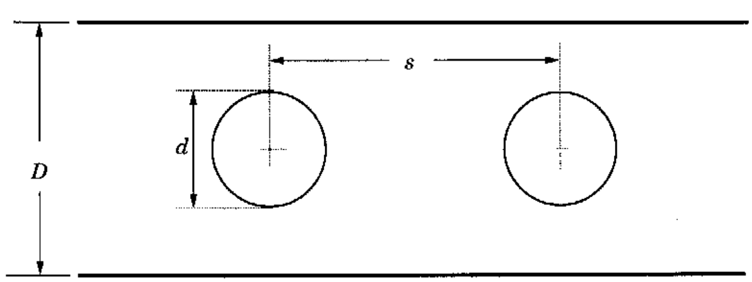

s
d
D

Fig. 7.

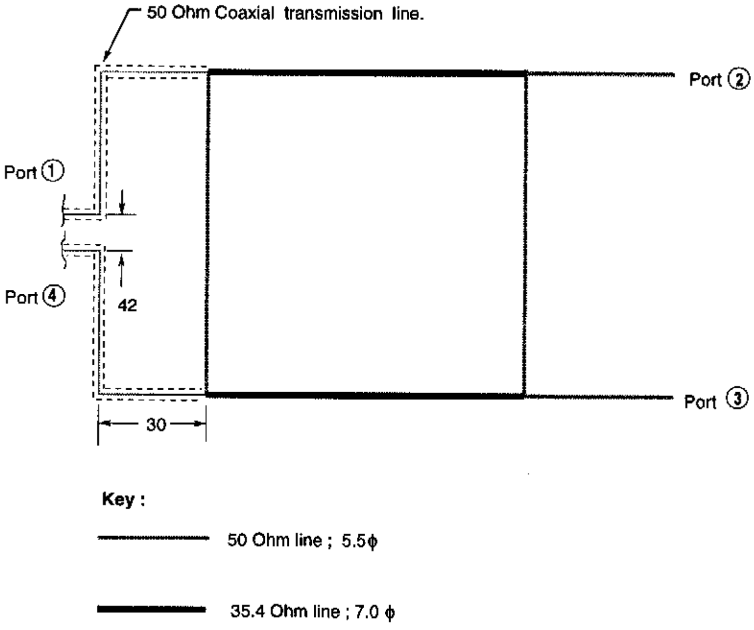


Fig. 8.

Fig.8. The coaxial 50–Ω line can be easily made for the 5.5 mm. dia. of the centre–conductor. An aluminium tube of 16 mm. O.D. and wall thickness of 1.6 mm will yield $Z_0 = 50.62\Omega$.

4 Scope for further work :

There exists more rigerous expressions for Eqns.(1) & (2), as per Ref.[2] and [3], which when employed may yield more accurate results. Rigerous design reviews can be made using such expressions.

5 References :

1. Johnson & Jasik (Eds.) **Antenna Engineering Handbook**,McGraw Hill Book Co., 1984 Edition; pp.42–4 to 42–10.

2. R.M.Chisholm *The characteristic impedance of Trough and Slab lines*,**IRE Trans. on Microwave Theory & Techniques**,Vol.MTT-4, July,1956. pp.166–172.

3. M.A.Gunston **Microwave Transmission–Line Impedance Data**, Van Nostrand Reinhold Co.,NY. 1972 Edition.