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Study and design of S-Band scan convertor for Tracking Radars

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Abstract: *In this paper, we design a scan converter for tracking radars. . In tracking Radars, multiple feeds are used in the Antenna system. The Signals from the feeds are processed to derive the error signal for tracking. In a tracking system employing three feeds, modules like power combiner and scan converter are used so that a single RF receiver can be used for both handling the data and to derive the error signal from the tracking.*

I. Introduction:

The unit takes three signals from the tracking Antenna system namely the left, the center and the right signals. These three signals are combined to give out ‘SUM’ and the ‘DIFFERENCE’ signals. The signals are used for both data handling and tracking.

The output of the power combiner unit is fed to this unit. It couples a portion of the different signal such that it gets added or subtracted with the sum signal by a switching signal. Thus a single modulated signal is produced so that only one Receiver can be used for both tracking and demodulating data.

In order to combine power combining from the antenna feeds and generate sum and the difference signal, a rat race coupler is used. Output of RRC is the sum (A+B) and difference.

Design Of Rat Race Coupler

A 180° Ring Hybrid (Rat-Race Coupler) is a four-port network with 180° phase difference between two ports. It is easier to manufacture this type of micro strip line component compared to a wave guide 180° hybrid junction, so called magic-T. The objective of this model is to compute the S-parameters and to observe the matching, isolation, and coupling around the operating frequency.

A rat-race coupler (also known as a hybrid ring coupler) is a type of coupler used in RF and Microwave systems. In its simplest form it is a 3dB coupler and is thus an alternative to a magic tee. Compared to the magic tee, it has the advantage of being easy to realize in planar technologies such as micro strip and strip line, although waveguide rat races are also practical. Unlike magic tees, a rat-race needs no matching structure to achieve correct operation.

The rat-race coupler has four ports, each placed one quarter wavelength away from each other around the top half of the ring. The bottom half of the ring is three quarter wavelengths in length. The ring has a characteristic impedance of factor $\sqrt{2}$ compared to port impedance.

A signal input on port 1, will be split between ports 2 and 4, and port 3 will be isolated. The full scattering matrix for an ideal 3dB rat-race is signal(A-B).This sum signal is directly feed to Coupled Line Coupler to generate the RF output and the difference output will feed to another RRC to give the two different outputs which are 180 degree out of phase. An SPDT (single pole double throw) switch is used to select one signal at a time. The RRC, SPDT switch and Coupled line coupler combined together and make a module called Scan converter. A Scan converter is a device which is used for mechanical switching of beams. The switching of beams is done by the switch. Switch is supplied with a 500 Hz oscillating frequency signal, hence it has a time period of 2ms.During one half of the time period one beam is selected and during another half time period it switches the other beam. Hence at any given time signal pertaining to the right or to the left is given as the output from the switch. Once the signal strength pertaining to left is received and once it’s pertaining to the right, so effectively there is difference in the signal strength of the received, which is observed, and this difference is proportional to the error voltage. So there is an effective amplitude modulation. If the AM voltage and reference voltage are in phase the error voltage is positive and the antenna has to move in a particular direction, if these voltages are out of phase the error is negative and antenna has to move in the opposite direction. This way the aircraft can be tracked easily.

$$S = \frac{-i}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 0 & -1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ -1 & 0 & 1 & 0 \end{pmatrix}$$

Rat-race couplers are used to sum two in-phase combined signals with essentially no loss or to equally split an input signal with no resultant phase difference between its outputs. It is also possible to configure the coupler as a 180 degree phase-shifted output divider or to sum two 180 degree phase-shifted combined signals with almost no loss.

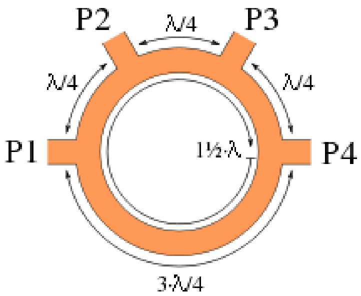
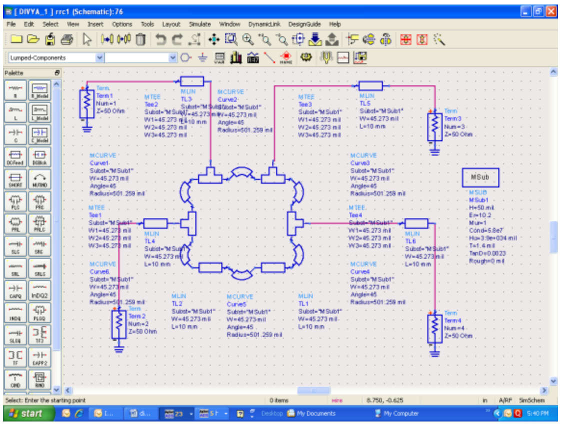
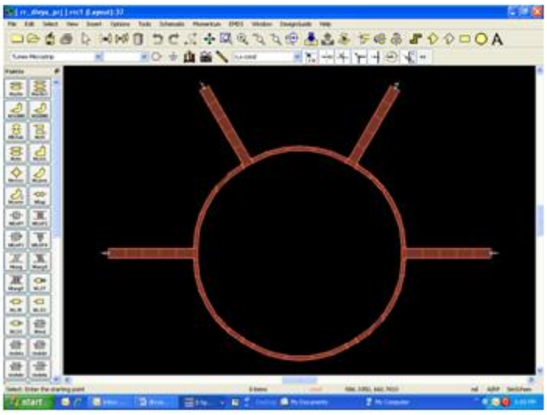


Fig.2.1 Hybrid ring (RR Coupler)

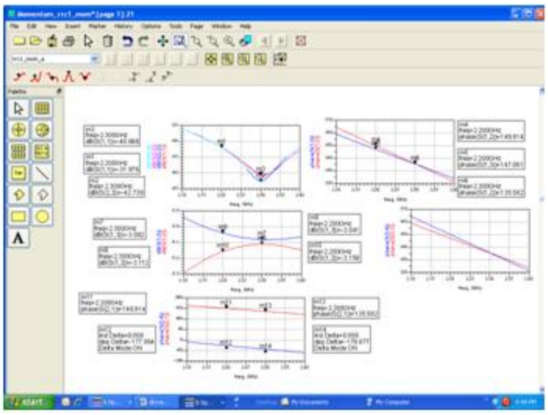
1. A rat-race coupler equally divides the power input at port 1 between ports 2 and 3. The signal at the output ports 2 and 3 are in-phase. Port 4 is isolated from port 1. If the signal is driven from port 2, then the power is divided between ports 1 and 4 with port 3 isolated. The signal at ports 1 and 4 are 180 degrees out of phase, and therefore this device is sometimes referred to as a 180-degree hybrid.
2. The design specifies the width and length of the micro strip lines to ensure that the ports are matched to Zo and equal power split is achieved at the design centre frequency.
3. The optimization minimizes the value of S11 (referenced to the value of Zo) at the design central frequency by changing the length of the ring.



Design Specifications:
1. Dielectric constant (Er) =10.2
2. Characteristic Impedance, Zo = 50 ohm
3. Height = 50 mil



Layout of coupled line coupler



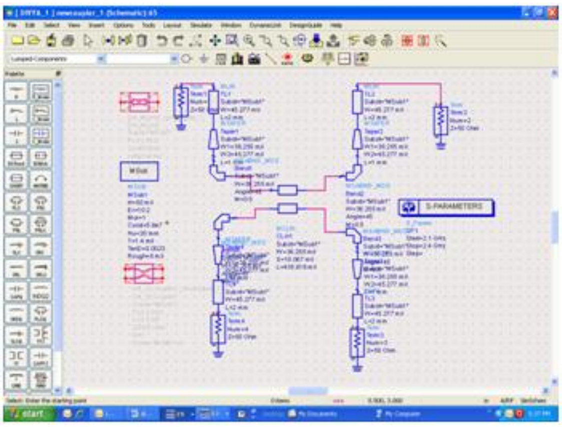
Resul of momentum simulation of coupled line coupler

II. Design of Coupled line coupler

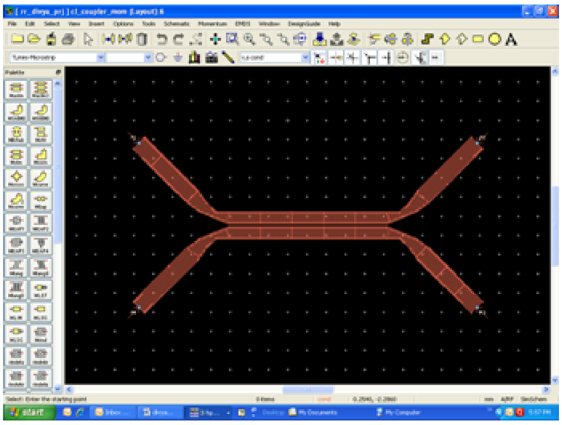
When two unshielded transmission lines are in close proximity, power can be coupled from one line to the other due to the interaction of the electromagnetic fields. Such lines are referred to as *coupled transmission lines*, and they usually consist of three conductors in close proximity, although more conductors can be used. Coupled transmission lines are sometimes assumed to operate in the TEM mode, which is rigorously valid for coaxial line and strip line structures, but only approximately valid for micro strip line, coplanar waveguide, or slot line structures.

Coupled transmission lines can support two distinct propagating modes, and this feature can be used to implement a variety of practical directional couplers, hybrids, and filters. The coupled lines are symmetric, meaning that the two conducting strips have the same width and position relative to ground; this simplifies the analysis of their operation.

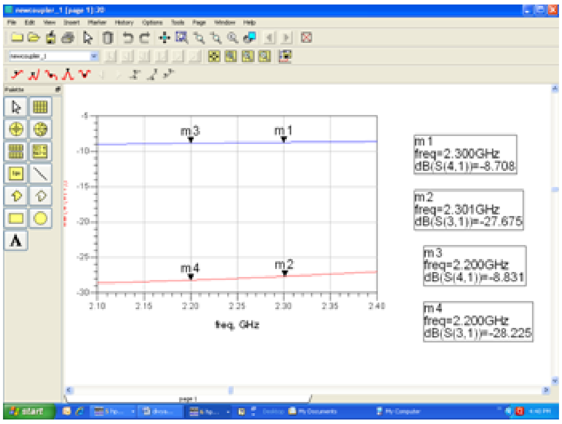
1. A coupled-line coupler outputs from the coupled port (pin 4) a fraction of the power presented at the input (pin 1). The remainder of the power is passed through to the output port (pin 2). The coupling coefficient specifies the ratio of the input power to the coupled power (P_1/P_4). The remaining port is isolated, although the isolation is often similar in value to the coupling coefficient for micro strip realizations.
2. The optimization minimizes the absolute difference between S41 in dB and the specified coupling coefficient at the design central frequency by changing the length of the coupled-line section.
3. The coupling coefficient must be positive and greater than 3 dB Best results are obtained for weak couplings of roughly 10 dB or more (C >10dB). Choosing the coupling coefficient too small can require spacing between the coupled lines too small to realize.
4. A Smart Component sub network is empty until the Design Assistant is used to generate the design.



Schematic of coupled line coupler



Layout of KSW-2-46 SPDT SWITCH



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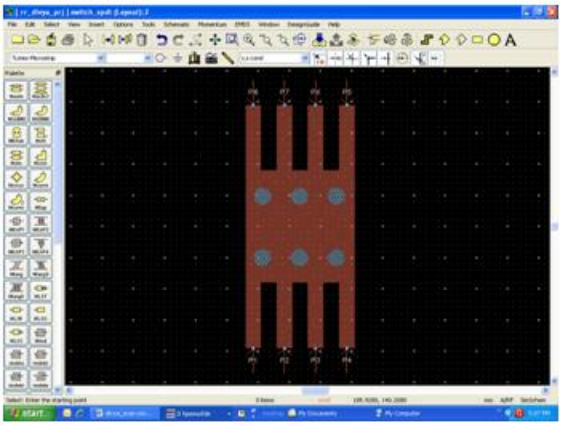
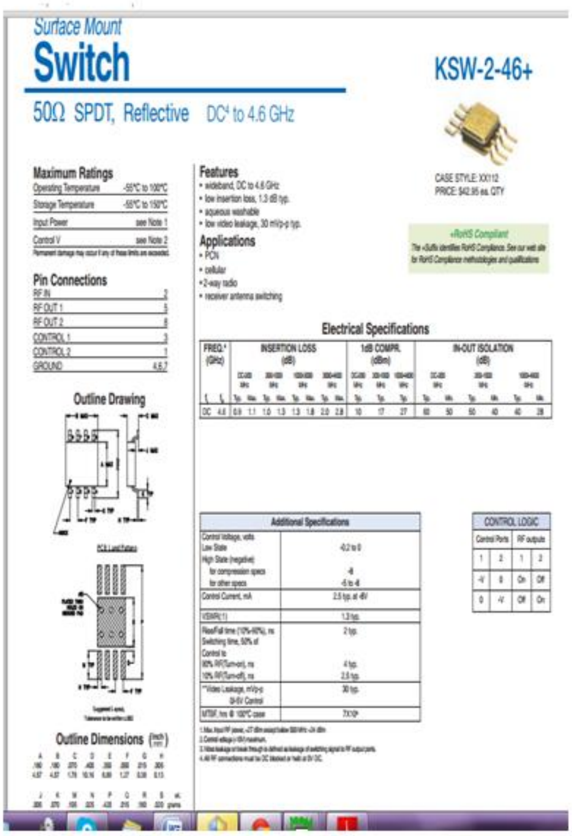
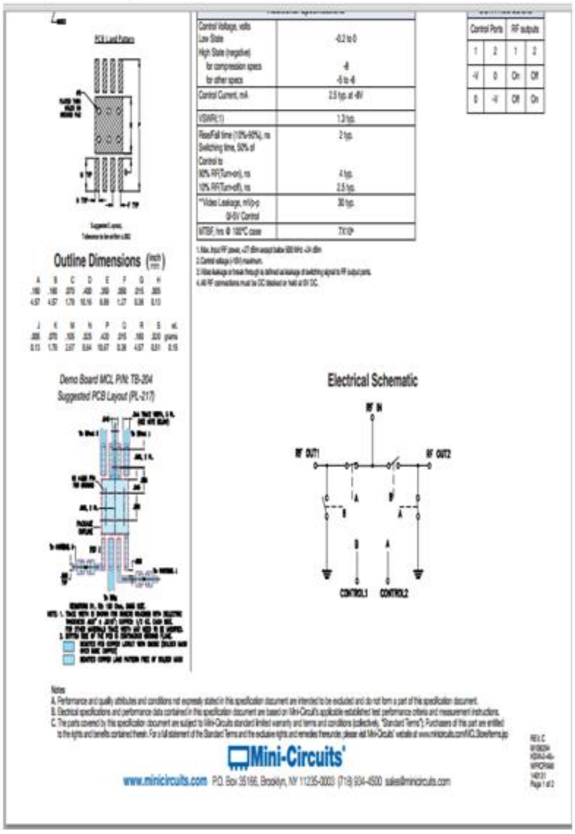
III. Design Of Spdt Switch

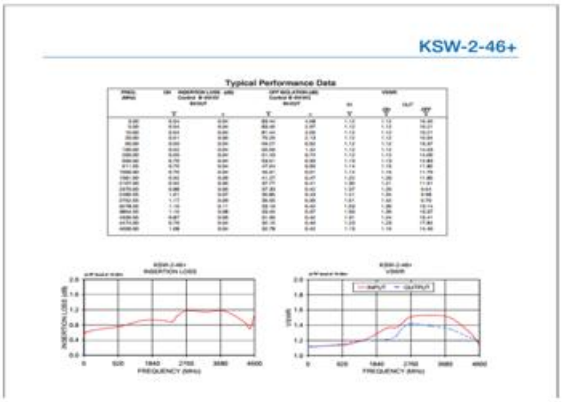
In order to switch between two signals coming from the Rat race coupler, SPDT switch is used that is single port double throw switch. The SPDT switch is implemented by using an IC KSW-2-46 by MINI CIRCUITS. It has two inputs and one output. Pin details and every other description of switch as given below:



Layout of KSW-2-46 SPDT SWITCH



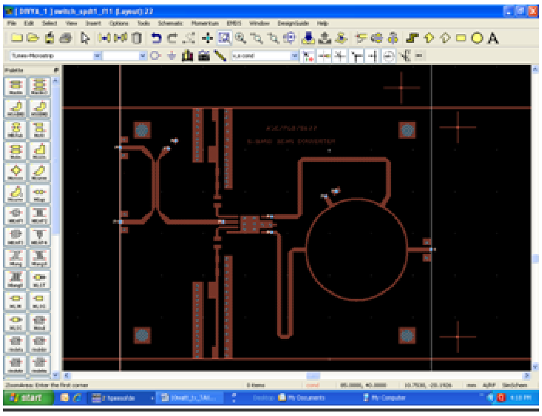




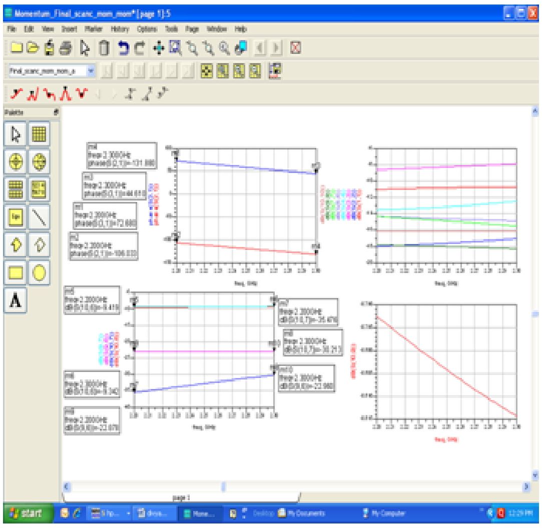
As indicating in the datasheet, the switch pad has been designed so that the switch sits on pads properly. The size of the switch IC is very small hence we design pads, so that it is easy to connect grounds, +5V or -5V and TTL input of the switch. The switch pad design is as shown in figure 4.1.

In order to provide ground to the switch we use printed through holes (PTH). The PTH's will ensure that the port is connected to the ground. From the RRC the two signals have to be coupled to the switch. Passive components like resistors and capacitors are used to couple signal to the switch. In my design, I have used three capacitors (1, 0.1, 0.01 microfarad) and one resistor of 50 ohm.

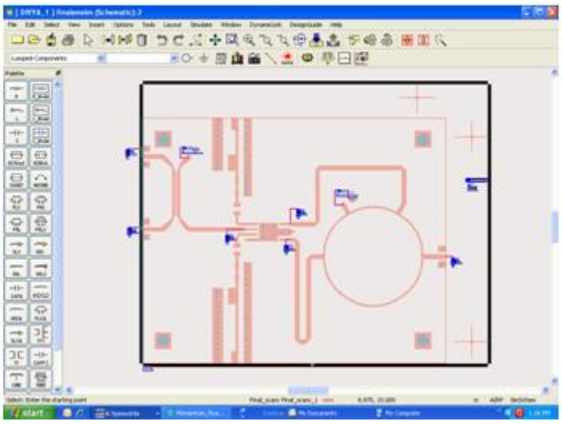
EM SIMULATION AND RESULTS



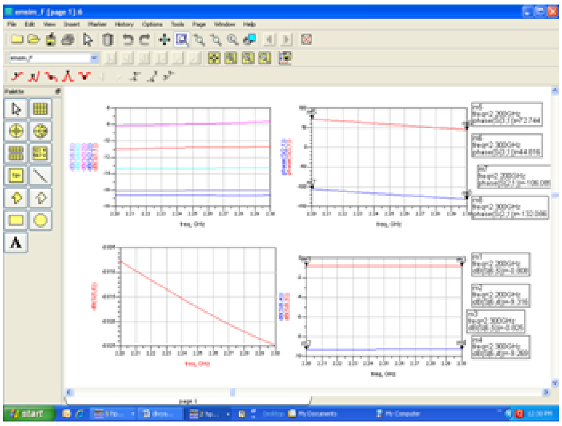
Final layout of Scan Converter



Result of Momentum simulation of scan converter



Schematic EM Simulation



Result of Em simulation

IV. Conclusion

The main advantage of this paper is that as it is attached with integrated patch antenna array it avoids the usage of another PCB for scan converter ,as well as the need of phase matched cables in the antenna feed circuitry. Scan convertor for integrated patch antenna is preferred because of its cheaper cost and ease of implementation. The future work to this paper is additional functionality can be included by implementing a bandpass filter and an LNA in the same PCB so that all components of tracking receiver can be realized as a single compact planar structure.

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