Mono-pulse Comparator Network System with Hybrid Rings

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***Abstract*— The Mono-pulse Comparator Network System (MCNS) with hybrid rings at frequency 2.4GHz is presented in this paper. The main objective is to provide the four feed signals for mono-pulse antenna. The methodology that is used for this work is the HFSS simulation, Photo-lithographic process and testing using SNA-2550.**

***Index Terms*— hybrid rings; micro strip circuits; mono-pulse antenna; mono-pulse comparator.**

I. Introduction

The antennas are used for the detection of moving target in Radar. While moving the target it is necessary to move or track the antenna along the direction of moving target. The mono-pulse antenna is one of the methods of realizing the tracking radar. Tracking radar used to measures the coordinates of the target.

The mono-pulse antenna uses four antennas and gathers angular position from one pulse [1]. Amplitude-comparison, phase-comparison and combination of amplitude & phase comparison are the techniques used for angle sensing in mono-pulse antenna [1] [2]. The student laboratory model of the radar system that can be used in mono-pulse tracking is described in [1]. It can be used for student laboratory exercises as a part of basic course of radar systems. The detailed description of the radar systems is presented in [2].

The dispersive characteristics of waveguides with different cross sections can be utilized for the phase compensation circuit to cancels the frequency characteristic of the delay line. A mono-pulse comparator using waveguide type and delay lines with phase compensation circuits presented in [3]. The review of the origins of technology and several example circuit topologies of passive microwave beam formers presented briefly in [4].

The method for designing of planar eight port waveguide mono-pulse comparator is suggested in [5]. Planar eight port waveguide mono-pulse comparator acts as a four-way in-phase power divider in a transmitting mode and as a mono-pulse sum and difference combining hybrid in receiving mode. Based on modified the Gysel power combiner using phase shifter and Ground Bridge for difference output a novel hybrid is proposed in [6].

To provide the sufficient design education and hardware exposure there is a strong need of hardcore engineers who are well equipped with design know how as well as practical knowledge to implement the circuits. Thus the SICO has launched the Advanced Micro strip Trainer Kit with technological know-how from IIT, Delhi [7]. The comparator based on the double-sided MIC magic-T is presented in [8]; this is the broad-band eight-port MIC mono-pulse comparator. To generate the sum and delta channel frequency responses, the comparator is fully characterized by its measured eight-port S parameters.

A novel super-broadband planar mono-pulse comparator based on a hybrid coupler derived from the conventional Wilkinson divider is presented, and demonstrated experimentally [9]. The design of a W-band waveguide mono-pulse comparator based on E- and H-plane couplers is presented [10]. E- and H-plane couplers are of hybrid 3-dB type and consisted of a coupling section and dielectric-slab phase delayer. A mono-pulse comparator is realized using two E- and two H-plane couplers in tandem.

For a W-band trans-twist reflect-array that performs the dual role of focusing the beam and twisting the polarization, a highly efficient mono-pulse comparator and feed network has been realized [11]. The assembly split-E-plane waveguide of four ring hybrids acts as a mono-pulse comparator network.

The lobe switching technique also known as sequential lobing has been discussed in [12]. The antenna beam can rapidly switched in between the two positions in the systems, thus the strength of the echo from the target will fluctuate at the switching rate, unless and until the target is exactly the midway between the two directions.

The main objective of this paper is to provide the four feed signals for mono-pulse antenna using Mono-pulse Comparator Network System (MCNS) using hybrid ring structure at 2.4 GHz frequency.

This paper is organized as follows: Section II, discuss in detail about the Mono-pulse Comparator Network System (MCNS). Section III introduces the hybrid rings. S-parameters & the design procedure of hybrid ring are presented in Section IV. Simulation & Fabrication part for the work is presented in Section V. The experimental results are presented in section VI. Finally, the conclusion of work is presented in section VII.

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II. MONO-PULSE COMPARATOR NETWORK SYSTEM

A Mono-pulse Comparator Network System (MCNS) is one which processes the four signals and can be constructed using a set of power combiners called as hybrids rings (hybrid couplers) and produces sum and difference of its input signals [6].

MCNS is used to calculate four return signals. The desired feed signals for mono-pulse antenna are SUM, ΔAZ, ΔEL, and ΔQ. The mono-pulse comparator takes the advantage of the property of Hybrid rings that it can be used as power combiner or power divider.

The MCNS with four hybrid rings is designed, by considering the FR_4 epoxy as substrate material having ε-value 4.4 with height 1.6mm. The ε-value 4.4 of dielectric-substrate technique is well suited for RF and microwave applications and easily available. The major challenge designing the 4-hybrid ring structure was the length of branches connecting in between the hybrid rings. At output port the lengths must maintain the same phase as input.

MCNS having the four inputs namely A, B, C & D produces the four output signals that are SUM, ΔAZ, ΔEL, and ΔQ as shown in Fig. 1. Where *l1* & *l2* are the branches connecting the hybrid rings.

$$\begin{aligned} SUM &= A+B+C+D \\ \Delta AZ &= (B+C)-(A+D) \\ \Delta EL &= (C+D)-(A+B) \\ \Delta Q &= (B+D)-(A+C) \end{aligned} \tag{1}$$

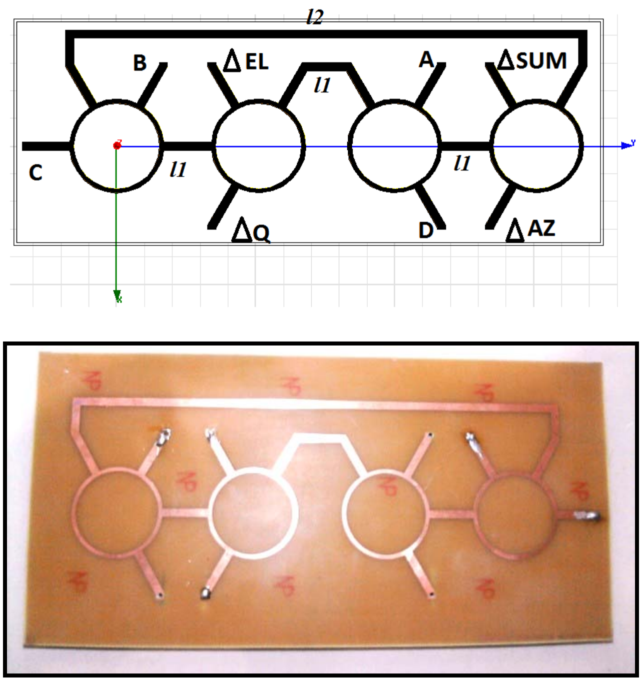


Fig. 1. Mono-pulse Comparator Network Systems (MCNS) with hybrid rings.

III. HYBRID RINGS

The MCNS designed using micro strip structure of the hybrid rings. The micro-strip circuits are finding increasing applications because of compactness, low weight and reduced cost [7]. The hybrid ring is the four port network with 180^0 phase shift between the two output ports. The important property of hybrid ring is that it can be used as power divider as well as a power combiner.

The terminology used to design the hybrid rings as discussed in detail in [7]. The impedance of I/O lines has been chosen as 50Ω & the same calculated for branches as 70.7Ω. The calculated values for inner radius, outer radius, and width for I/O lines & width for branches are 15.5mm, 17mm 3mm, 1.5mm respectively. The lengths of branches *l1* & *l2* connecting the hybrid rings are 17.5mm & 214mm respectively. The detail design procedure for MCNS with hybrid rings is discussed in Section IV.

IV. S-PARAMETERS & DESIGN OF HYBRID RINGS

The scattering parameters of a general hybrid rings as discussed [7] given by:

$$[S] = \begin{bmatrix} 0 & -j\overline{Yb} & 0 & j\overline{Ya} \\ -j\overline{Yb} & 0 & -j\overline{Ya} & 0 \\ 0 & -j\overline{Ya} & 0 & -j\overline{Yb} \\ j\overline{Ya} & 0 & -j\overline{Yb} & 0 \end{bmatrix} \tag{2}$$

For perfect match at input

$$S11 = 0 \Rightarrow \overline{Ya^2} + \overline{Yb^2} = 1 \tag{3}$$

Power division is controlled by branch admittances

$$\begin{aligned} \overline{Ya} &= Ya/Yo = \frac{1}{\sqrt{2}} \\ \overline{Yb} &= Yb/Yo = \frac{1}{\sqrt{2}} \end{aligned} \tag{4}$$

3-dB rat-race hybrid coupler reduces to

$$[S] = \begin{bmatrix} 0 & \frac{-j}{\sqrt{2}} & 0 & \frac{j}{\sqrt{2}} \\ \frac{-j}{\sqrt{2}} & 0 & \frac{-j}{\sqrt{2}} & 0 \\ 0 & \frac{-j}{\sqrt{2}} & 0 & \frac{-j}{\sqrt{2}} \\ \frac{j}{\sqrt{2}} & 0 & \frac{-j}{\sqrt{2}} & 0 \end{bmatrix} \tag{5}$$

Hybrid ring can be designed in following steps

Step-1] Selection of substrate parameters- ε-value, h, Z0

Step-2] Calculations of Y0, Ya, Yb values as discussed

Step-3] Calculation of 'w' for I/O lines & branches

$$\frac{w}{h} = \frac{8e^{A}}{e^{2A}-2} \tag{6}$$

Where,

$$A = \frac{Z0}{60}\sqrt{\frac{\in r+1}{2}} + \frac{\in r-1}{\in r+1}\left(0.23 + \frac{0.11}{\in r}\right) \quad (7)$$

Step-4] Calculation Єeff1 & Єeff2

$$\in eff = \frac{\in r+1}{2} + \frac{\in r-1}{2}\left(\frac{1}{\sqrt{1+12h/w}}\right) \quad (8)$$

Step-5] Calculation of Radius '*r*'

$$\lambda o = \frac{c}{f} \quad (9)$$

$$\lambda g = \frac{\lambda o}{\sqrt{\in eff2}} \quad (10)$$

$$r = \frac{3\lambda g}{4\pi} \quad (11)$$

Inner Radius: $ri = r - w/2$ (12)

Outer Radius: $ro = r + w/2$ (13)

Step-6] Length of the branches connecting hybrid rings

Branch1: $l1 = \lambda g / 4$ (14)

Branch2: $l2 = 3\,\lambda g$ (15)

V. SIMULATION & FABRICATION

The MCNS is simulated using the HFSS simulation software. While simulating the MCNS, the consideration was the total width of the PCB should not exceed the limits, since it will take long time and will not simulate the structure. The same structure has been fabricated by using the Photolithographic process.

VI. EXPERIMENTAL RESULTS

The MCNS has been tested by using the ELAD SNA-2550, having frequency range 100 KHz to 2.6GHz and 50ohm normal impedance. The setup for experiment is as shown in Fig. 2.

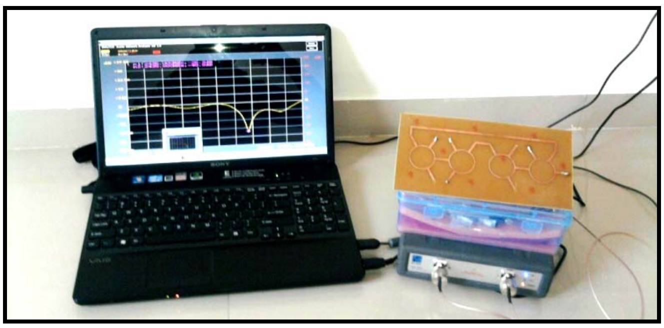


Fig. 2. The MCNS testing using the ELAD SNA-2550

The experimental results are tabulated in Table-I and same results are as shown in Fig. 3, Fig. 4, Fig. 5, & Fig. 6. As per the experimental results shown above, we can see that MCNS achieves VSWR as equals to 1 for all the input port. It is equal to 1.2 at port A and 2.0 at port C. The return loss as -20.6dB at port A and -10.0dB at port C. Thus, MCNS provides excellent standing wave ratio and also provides returns loss below the -10dB at each port.

TABLE I EXPERIMENTAL RESULTS FOR 4-INPUT PORTS

Experimental Results for Inputs	A	B	C	D
SWR	1.2	1.7	2.0	1.7
Return Loss	-20.6dB	-12.0dB	-10.0dB	-11.7dB
Output at SUM	-20.2dB	-21.3dB	-24.3dB	-25.3dB
Output at ΔAZ	-4.3dB	-14.1dB	-14.5dB	-5.2dB
Output at ΔEL	-10.9dB	-8.7dB	-6.9dB	-10.8dB
Output at ΔQ	-12.3dB	-9.3dB	-6.9dB	-9.7dB

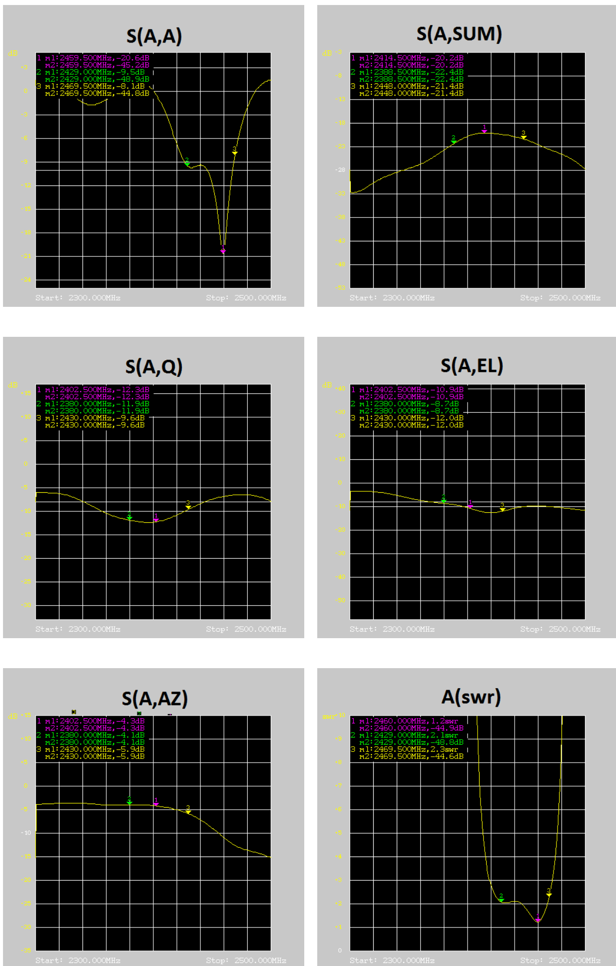


Fig. 3. SWR, Return loss and output results for Input A with different outputs

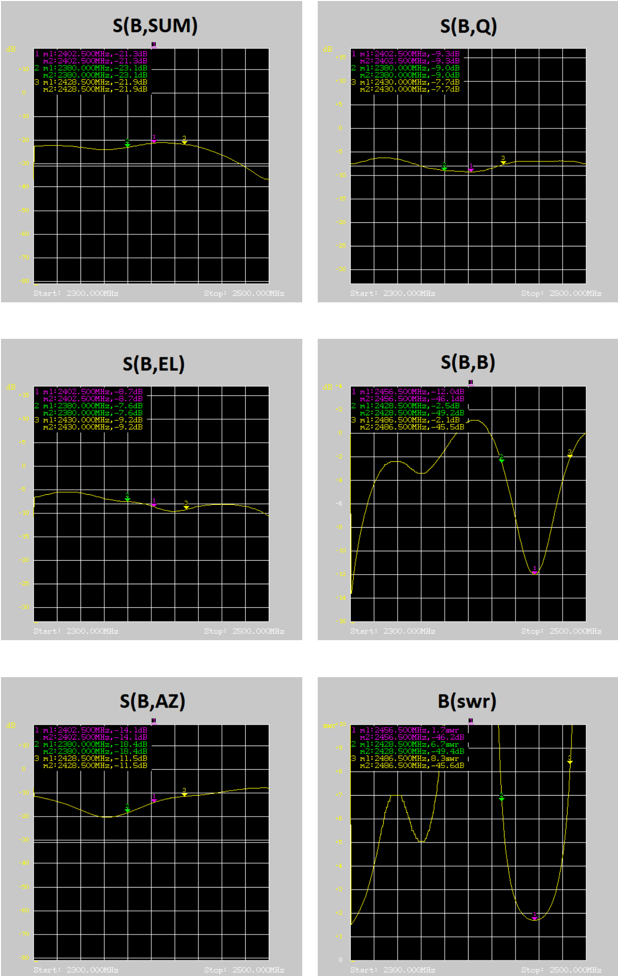
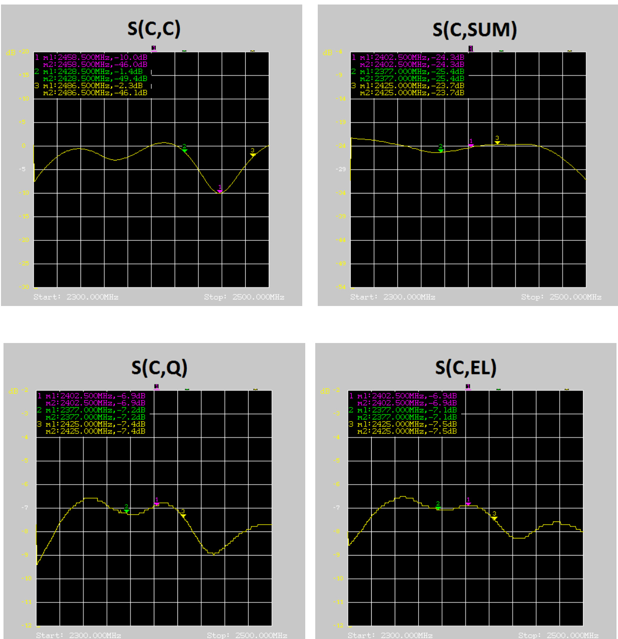


Fig. 4. SWR, Return loss and output results for Input B with different outputs



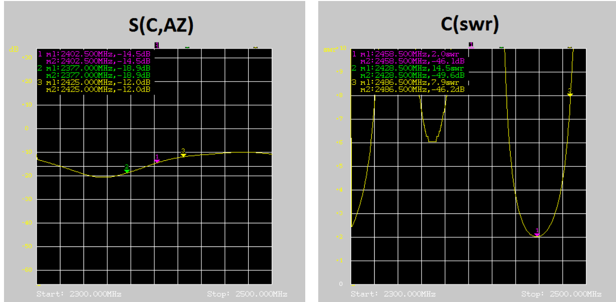


Fig. 5. SWR, Return loss and output results for Input C with different outputs

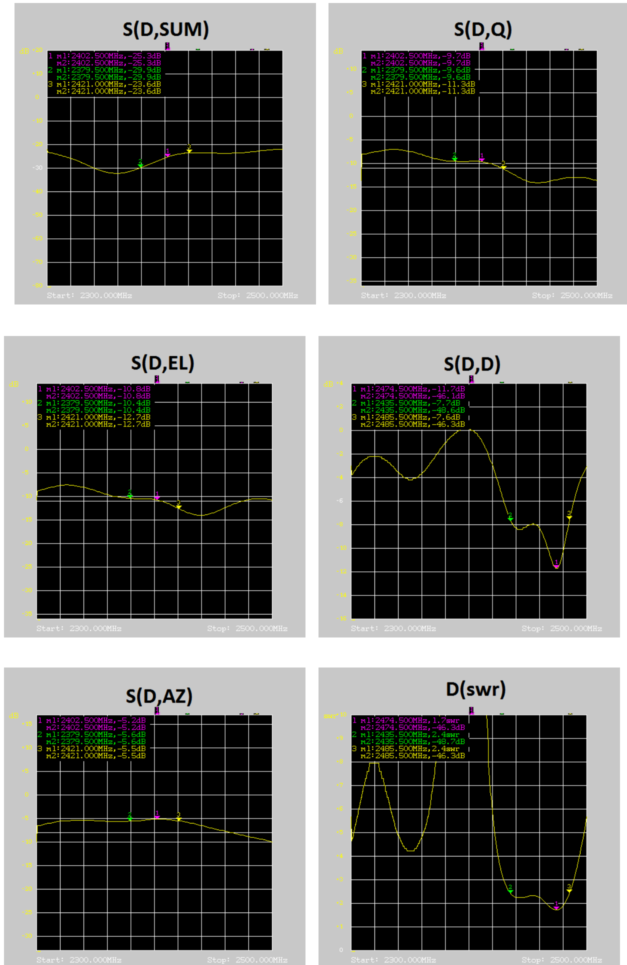


Fig. 6. SWR, Return loss and output results for Input D with different outputs

VII. Conclusion

The Mono-pulse Comparator Network System (MCNS) presented in this paper provides excellent standing wave ratio and also provides returns loss below the -10dB at each port. As per the requirement of Mono-pulse antenna we found the four signals for the four feeds of the Mono-pulse antenna. The four output signals of MCNS can be easily used to the feeds of the antenna and hence we can conclude that

MCNS can be mounted on Mono-pulse antenna and it will work effectively.

REFERENCES

[1] Davor Bonefacic, Julijana Jancula, and Ninoslav Majurec, "Model of a monopulse radar tracking system for laboratory," Radioengineering, Vol. 16, No. 3, pp. 62-67, September 2007.

[2] M. I. Skolnik, Introduction to Radar Systems. 3rd edition, Tata McGraw-Hill, New York, 2001.

[3] M. Saitoh, H. Uchida, N. Yoneda, K. Kakizaki, Y. Konishi, and H. Oh-hashi, "A broadband waveguide monopulse comparator with phase compensation circuits," Proceedings of ISAP2005,Seoul,Korea, pp. 833-836, 2005.

[4] Ken greenwoods, Passive RF & Microwave beam forming networks, TRM Microwave, Technical Publication, pp. 1-10.

[5] M. Mohammadi and F. H. Kashani, "Planar eight port waveguide mono-pulse," Progress in Electromagnetics Research C, Vol. 6, pp. 103-113, 2009.

[6] M. Fartookzadeh, S. H. Mohseni Armaki and M. Kazerooni, "A novel 180^0 hybrid based on the modified Gysel power divider," Progress In Electromagnetics Research C, Vol. 27, pp. 209-222, 2012.

[7] "Advanced micro strip trainer kit User's Manual," The Scientific Instruments Co. ltd., IIT Delhi.

[8] Xie Junwei, Zhang Xuchun, Tong Chuangming, and Zhang Xiaokuan, " A Double-sided broad-band eight-port monopulse Comparator," Asia-Pacific Microwave Conference, APMC 2007, pp. 1-2, Dec 2007.

[9] N. Yang, C. Caloz, and K. Wu, "Monopulse comparator with frequency-independent delta-channel nulls for high-resolution tracking radar," Electronics Letters, Vol. 47, Issue: 5, pp. 339-340, March 2011.

[10] B. Enkhbayar, Jae-Hoon Bang, Eun-Jong Cha, and Bierng-Chearl Ahn, "Design of a w-band monopulse comparator based on E- and H-plane waveguide couplers," IEEE 11th Annual Wireless and Microwave Technology Conference (WAMICON), pp. 1-5, April 2010.

[11] D. R. Jahagirdar, "A highly efficient monopulse comparator and feed assembly for a W-band trans-twist microstrip reflect-array," IEEE Antennas and Propagation Society International Symposium (APSURSI), pp. 1-4, July 2010.

[12] G. Kennedy, and B. Davis, Electronic Communication Systems, 4th edition. New Delhi: TataMcGraw-Hill, 2004.