Design and Development of Optical Control Network for 1024 Element Active Phased Array Radar

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Abstract:

In this paper, we present the design and development of the optical network for Indian MST 1024 Active Phased Array Radar[1]. The active phased array radar is mono static and operated frequency is 53MHz. This radar consists of 1024 elements of yagi antenna and each connected to one solid state transmit-receive module which is located in the field. The Transmit-Receive module (TR module) works based on four control signals namely transmit and receive Ethernet commands, Inter Pulse Period (IPP) and clock (CLK). Earlier we used to transfer these signals through normal electric cables. The signal speed and bandwidth are limited in the case of electric cables. In addition to this, the electromagnetic interference of the electric cable also affects the transmit and receiving signals. Besides, these limitations the electrical cables cannot be used in lightning prone areas as they carry the electrical signals which in turn affect the switch ports, etc. To overcome these problems, we developed an optical control distribution network for active phased array radar. We used this technology to interface between solid state transmit - receive module and radar controller and automatic calibration.

***Keywords:** Active Phased Array Radar, Transmit-Receive module, Ethernet commands, Optical Control Distribution Network.*

INTRODUCTION:

The Indian MST Radar located at National Atmospheric Research Laboratory is being operated for atmospheric research application for two decades. Presently 53MHZ, 1024 element radar transmit systems are tube based. The major challenge with the existing transmitter units is the degradation due to ageing. Further, critical high power spare parts are getting obsolete making it difficult to sustain the radar operation. To sustain the radar operations for a long run, an R&D project was taken up to upgrade the Indian MST radar into a fully active phased array system using the solid-state Transmit-Receive (TR) modules. 1024 element active phased Array radar is developed with latest technology. The control signal distribution of this radar forms the crucial area for providing high speed data interface links for fast and coherent transmission.. Conventional radar system[2] has lots of electrical cables along with its complex connectivity. Hence power, distortion of signals, EMI/EMC problems, less bandwidth has narrowed down secure and fast transmission. To make radar system more efficient, all control signals are converted into optical signals for distribution.

I. Schematic of Control System for Active Phased Array Radar

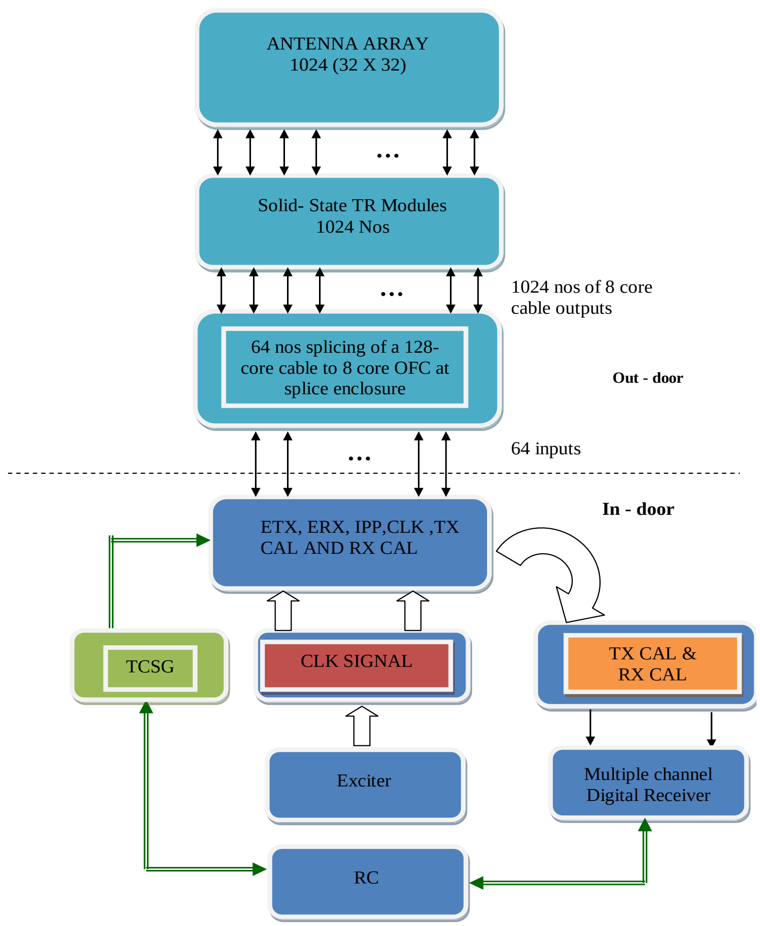

Figure: 1 Block Diagram of optical control network

The fiber optic control network is the media used for transmitting the 1) Ethernet commands, 2) IPP and 3) Clock signals (CLK) 4) RF Tx-Rx signals for calibration to TR modules and to receive status from the TR modules located in the antenna field. These signals are generated in Control and Instrumentation room (CI room) and sent to the TR modules which are distributed in the antenna array of aperture of 130 m X 130m. An Ethernet protocol is used to send commands (TX) and to receive status (RX) from all the 1024 TR Modules. IPP and Clock signals are used for the generation of various timing signals within the TR module. Apart from these two signals for calibration will be distributed along with them.

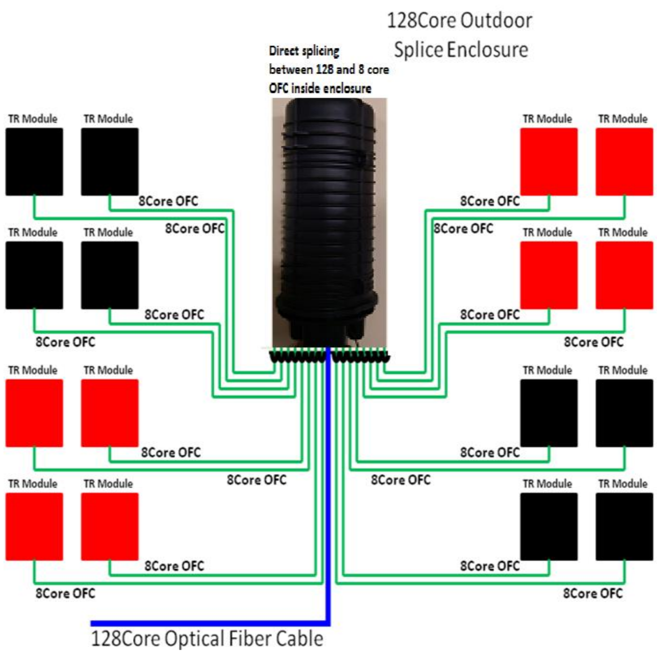

Figure: 2 Outdoor Splicing Schematic

In the antenna array, the 1024 TR modules are configured as 64 groups with each group having 16 TR modules (4 X 4 arrays). Each TR module requires the following communication links such as IPP, clock, Tx Ethernet link, Rx Ethernet link, cal Tx, Cal Rx Hence effectively, 8 cores are required for each TR module and each group needs 128 (16x8) signal lines. So, 8 core cables is planned from 1:16 splicing junction to individual TR module and 128 core fiber optic cable is proposed from huts to field. A total of 64 numbers of 128 core cables enter the antenna field.

The fiber optic feeder network configuration is illustrated in figures 1.The Ethernet signals (Tx and RX) are distributed to all the TR Modules using Optical Switches brought from M/s Allied Telesis. There are 256 NOS of such switches each with 24 ports.

These switches are provided with LC type optical connectors. These optical signals are terminated in patch panels located in CI room.

CLK and IPP signals are split using circuitry and optical media convertors. The media convertors used are HFBR14E4Z from M/s Avago. Each splitter has 16 optical outputs and 64 nos of such splitters are used for IPP and another 16 nos. for clock signals. These optical outputs are terminated at patch panels located in the CI room. The patch panel outputs are routed to the antenna field using 128 core fiber optic cables and in the field they are terminated in the outdoor splicing units from where they are distributed to TR modules using 8 core FO cable. Outdoor splicing schematic shown in Figure2.

All the optical switches, CLK splitters, IPP splitters and patch panels have to be integrated in Fiber Cable Management Racks. This has to be neatly executed.

Ethernet optical signal distribution:

. The Ethernet signals (TX and RX) are distributed to all the TR Modules using Optical Switches. The present case we have used 64 nos for distributed and 4nos of centerlizied of AT-9000/28SP high performance Gigabit Ethernet switches from M/s Allied Telesis Each switch have 28 port Gigabit managed ‘Green’ switch with 24 100Mbps SFP ports and 4 100T. It has the ability to match the fiber SFPs to meet distance, noisy industrial or security these switches are provided with LC type optical connectors. These optical signals are terminated in patch panels located in control instrument (CI) room further it is connect to the field located TR module through fiber cables. Photography of the Ethernet switch is shown in figure3.

Figure: 3 Optical Ethernet Switch

Clock and IPP signal distribution:

16 MHz clock (CLK) and inter pulse period (IPP) signals are split using circuitry and optical media convertors. The media convertors used are HFBR 14E4Z from M/s Avago. The HFBR-14E4Z fiber optic transmitter is designed to operate with the Avago Technologies HFBR-24x6Z fiber optic receiver up to 160MB. This part is characterized with 62.5/125 µm multimode fiber optic cable. Multi-mode fiber cables are described by their core and cladding diameters. Thus, 62.5/125 µm multi-mode fiber has a core size of 62.5

micrometers (µm) and a cladding diameter of 125 µm. The transition between the core and cladding is a gradual transition, which is called a graded-index. Here in our total control system multimode cables are used. its characteristics are given in table 1.

Sl No.	Parameter	Values
1	Material (Core / Cladding)	glass / glass
2	Index Profile	Graded Index
3	Fiber type	multi-mode
4	Core diameter	62.5 ± 2.5 um
5	Cladding diameter	125 ± 1 um
6	Wavelength	850 and 1310 nm
7	Insertion Loss	≤ 0.2 dB
8	Return Loss	≥ 26 dB

Table: 1 Characteristic Multi mode cable

The IPP and CLK signals are splitted by using optical splitters. Each splitter has 16 optical outputs and 64 nos. of such splitters are used for IPP and another 16 nos. for clock signals. These optical outputs are terminated at patch panels located in the CI room.

II. Optical Transmit-Receive Calibration

In Phased array Radar, for proper beam forming and steering the beam, it is very much essential to precisely set the amplitude and phase of each element channel. The variation of amplitude and phase with in the channel because of complex involvement of various RF systems, RF cables and harsh temperature environment. Due to Phase and amplitude characteristic variation of all elements, SNR degradation will occur. In order to equalize the phase and amplitude effect of the channel phased array radar need to calibrate periodically. Conventional methods of calibration[4] are near field scanning probe method, polarimetric technique, and mutual coupling method. The conventional methods used for calibration is a time consuming involving lot of man power. In order to overcome these limitations the calibration is done automatically through optical mode.

III. Conclusion

The optical control network technology for 1024 Element Active Phased Array Radar has been designed, developed and validated with the results of winds power spectrum along with GPS SONDE. In addition to these two, the limitation of the speed and bandwidth in the electric signals which was being used in the earlier system is totally removed with the help of optical control network. This optical control network can also be used in lighning prone areas unlike the electrical cables.

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BIOGRAPHY:

P.Kamaraj, born in 1975, passed B.E.(E.C.E) at Anna University, Chennai, in 2004 and M.E (VLSI) at Anna University in 2009. He joined NARL in 2006. He is involved in the development, installation and commissioning of the wind profilers, Active phased array VHF Radar, HF Radar Interferometer at NARL. His areas of interest include active phased array radars and radar calibration.

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K.M.V.Prasad received his B.Tech. degree in Electronics and Communication Engineering from Sri enkateswaraUniversity College of Engineering (SVUCE) SV University (SVU), Tirupathi. He joined NARL in April 2014. His areas of interests include digital implementation of controllers using FPGA devices, digital signal processing, data acquisition systems and Radar systems.

Jeldi Kamal Kumar born in 1991. Passed B.Tech (Avionics) from IIST, Trivandrum. Joined semi-conductor laboratory at Mohali in November, 2013 and at NARL in December 2014. His areas of interest include development of radar controllers and health status monitoring tools for Radars.

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