Design and Realization of Single and Multi-band Monopulse Feed using Horn and Dielectric Rod for LEO Satellite Tracking Application

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by

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ABSTRACT

Ground station antennas play an important role in satellite communication serving as a link between orbiting satellite and receive-chain-electronics & data processing system. Large reflector antennas, along with suitable feed such as horn antennas in various configurations, are mainly used as ground station antenna. For reception of data from Low Earth Orbiting (LEO) satellites, these large reflector antennas along with feed and associated electronics must be equipped with suitable tracking techniques such as Monopulse. Design methodologies of ground station antennas, basics of reflector, feed for reflectors such as horns and dielectric rods, Different satellite tracking methodologies along with monopulse tracking for single and multiband operation are key highlights of the present thesis.

Another important aspect of receiving ground station is the mitigation of interference/noise from adjacent channel. In this thesis, Split Ring Resonator (SRR)-based horn-filtenna, comprising circular SRR array integrated in the throat of a X-band horn antenna, is proposed to overcome interference problem in receiving ground station. A linear array of circular SRR elements arranged in staggered configuration is used as an inline filter, installed inside a standard horn antenna. The dimensions of SRR elements are tailored in such a way that it provides a wide notch bandwidth (315 MHz) response with higher gain suppression (more than 35 dB). Detailed design, simulation, realization followed by extensive measurements of the realized horn-filtenna using network analyzer and Compact Test Range Facility (CATF) facility is reported in one exclusive chapter of the thesis.

Tracking of remote sensing low earth orbit (LEO) satellites are extremely crucial for error free data reception. Out of different tracking techniques, monopulse tracking is chosen because of its superior performance in terms of tracking accuracy, mechanical simplicity and low SNR value. In monopulse tracking feed, Sum and Difference patterns are considered simultaneously for optimization. Out of different monopulse tracking configurations (four element, multimode, twelve horn etc.), five element feed is selected because of its simple configuration, less hardware, independent optimization of Sum and Difference mode and very low pre-LNA loss. Design and realization of X- band dual-polarized monopulse tracking feed for

LEO satellite ground station is described in detail in this thesis. This proposed five element feed, with a corrugated horn at the center and four circular septum polarizers at the periphery of the horn as tracking waveguide, is designed for a 4.5m Cassegrain reflector system. Designed feed, characterized in LAB and CATF for refection and radiation characteristics, exhibits excellent resemblance with measured and simulated results. After installation of the feed in 4.5m reflector, G/T is measured with terrestrial sources and shows a reasonably high value (29 dBK^{-1}). With the realization of single channel monopulse tracking, this feed is currently operational for real time satellite tracking at ground station of National Remote Sensing Centre, ISRO, Hyderabad, India.

Study of monopulse feed is further extended from single band to dual band operation, where a composite dual-band, dual-polarized monopulse tracking feed, covering S- and X-band frequencies, is designed for a 7.5m reflector antenna. In the proposed dual band feed, the X-band feed is a five-element monopulse feed, consisting of a corrugated horn as the main element, surrounded by four circular septum polarizers serving as tracking elements. On the other hand, S-band feed is a four-element monopulse feed consisting of a square dielectric array arranged in 2×2 configurations. Design, simulation, characterization, measurement and realization of S-X band composite feed is described in detail. The designed S-X feed, where S-band and X-band feed are collocated in same cassegrain plane, is very compact, simple, easy to fabricate and an optimum one for S–X dual-band operation. High illumination efficiency (more than 90 %) along with high G/T ratio (32 dBK^{-1} and 18 dBK^{-1} for X- and S-band respectively) is obtained after integration of the feed with a 7.5m reflector.

As communication band in modern remote sensing satellites are moving towards the higher frequency range in search of more bandwidth to cater to the need of high data rate requirement, design of monopulse composite feed is further extended to higher band of frequency i.e Ka-band frequency (25.5 -27 GHz) supported with S-band (2.025 -2.3 GHz). Different design aspects of S-Ka band composite monopulse feed along with extensive characterization and realization detail is reported in this thesis. Ka-band feed is realized with five element configuration with corrugated horn as main horn and four flared waveguides as tracking elements while S-band, similar to S-X feed, is an array of four dielectric rod, fed with circular

septum polarizer. Detailed design, simulated and measured results, obtained from CATF testing and network analyzer, are presented in an elaborate fashion in the current thesis.

In this thesis realization of three different monopulse feeds, one single band (X-band) and two dual band (one S-X and other S-Ka-band) dual polarized monopulse feed is designed, realized and practically implementedThis thesis contributes in providing design guidelines and realization details of ground station monopulse tracking feed, an important element of satellite receiving system.